بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Sudan University of Science and Technology

College of Graduate Studies

# Use of Tidal Energy as Renewable Energy

# استخدام طاقة المد والجزر طاقة متجددة

*A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of master in physics*


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# Table of Content

# Dedication

I dedicate this research to my sweetie mother and precious father

# Acknowledgment

I would like to express my deep gratitude to my master thesis supervisor Dr.Sawsan Ahmed Elhouri for guidance and helped me in all the time of research and writing of this thesis. Also, I would like to thank my family, relevent,friend, and my colleague in the Sudan University of Science and technology

# Abstract

Currently climate change represents the focus attention of the global world and how to reducing greenhouse gas emission, which led to use other energy source, especially renewable energy source, Tidal power it is a renewable and clean source of energy, can represent a solution of the many environmental pollutants resulting from use another energy source, besides this source exposed to exhaustible as a result of intensive use. Tidal power is unconventional sources of energy which is similar to hydropower renewable energy source; just the difference in the generation method, tidal power generates electricity from the flow of the tide. The location of tidal power plant is very important process and it has a certain condition must be taken into account in the selection, Tidal power source had many advantages over other renewable sources such as predictability This thesis displays the physical principles of tidal energy and the various methods of utilizing tidal power to generate electricity. It illustrates the main feature (operating mode) of tidal power plant (tidal barrage and tidal current turbines) and detailed explanation about tidal energy mechanism and some of the environmental effect. Also, it briefly discusses the research has been done on the possibility of construct tidal power plant in red sea Sudan.

# المستخلص

مؤخرا أصبح تغير المناخ وكيفية الحد من الغازات المنبعثة في الغلاف الجوي المسببة للإحتباس الحراري محط أنظار العالم أجمعه .مما أدى إلى إستخدام مصادر بديلة للطاقة ،خاصة مصادر الطاقة المتجددة .وتعتبر طاقة المد والجزر من المصادر المتجددة والنظيفة حيث أن إستخدامها يمكن ان يساعد على التقليل من الملوثات البيئية الناتجة من إستخدام المصادر الأخرى . حيث ان المصادرالأخرى المستخدمة عرضه للنضوب للإعتماد الكبير عليها في انتاج الطاقة منذ القدم .طاقة المد والجزر من المصادر غير التقليدية وهي شبيهة بالطاقة المائية، حيث أن الاختلاف بينهم يتمثل في طريقة توليد الكهرباء، فطاقة المد والجزر تعتمد في توليد الكهرباءعلى تدفق الماء نتيجة للمد والجزر ويعتبر اختيار الموقع بالنسبة لمحطة التوليد عملية مهمة جدا حيث ان هنالك شروط معينة يجب اختبارها اثناء اختيار الموقع الأمثل.تتميز هذه الطاقة على بقية المصادر المتجددة بأنها متوقعة(يمكن التنبوء بها).إحتوى هذا البحث على ألمبادئ الفيزيائية لظاهرة المد والجزر والطرق المستخدمة في توليد الطاقة الكهربائية منها، شرح مفصل عن آليةعمل محطة توليد الطاقة و ناقش أيضا بعض الدراسات التي أجريت على البحر الاحمر بمنطقة بورتسودان لمعرفة إمكانية إنشاء محطة توليد بها .

# Chapter One
# Introduction

## 1.1 Introduction

Energy is the main boost for social and economic development and its represent an indication of the country progress .necessity of energy increase with global population growth .there are several energy source all of them contribute to cover the world energy demand, energy source classified into two types according to (exhaustible or inexhaustible of the source) renewable and non-renewable energy source. A non-renewable energy source such as (fossil fuel and nuclear material) and the renewable energy source such as (Sunlight, wind, wave and tide) all this natural plant converted into usable energy form used in electricity generation, transportation, and water heating/cooling. Previously main dependence on fossil fuel( coal, oil, and natural gas) for energy production have clear effect for developing of economic progress, but at the same time, various environmental impact comes out led to the tendency of using alternative energy source which is non-polluting ,associated with the environment.

## 1.2 Research Problem

All the world tend to use renewable and clean energy source to avoid most of the environmental problem originated from using another energy source (nuclear energy ,fossil fuel) ,for example, combustion of the fossil fuel

which represents the mandatory source of the energy around the world for a long time as the result of this heavy dependence on the fossil fuel source ,it will deplete within coming decades also concentrating on combustible fossil fuel releasing wide range of environmental pollutant such as (carbon dioxide ) , resulting in raising the global temperature( global warming ) furthermore lead to the climate change. Also utilizing nuclear energy source residue danger toxic waste .therefore there is extensive public support for using clean energy source, which provides electricity without giving rise to any carbon dioxide emission. So tidal energy is a renewable energy source (energy dissipated by tidal movements) has a significant advantageous over the many forms of renewable energy source because it more controllable and predictable

## 1.3Literature Review

**Wave and tidal current energy – A review of the current state of research beyond technology**

***Andreas Uihlein , Davide Magagna***

**Abstract**

The oceans of the earth offer vast amounts of renewable energy. Technologies to harness the power of the seas are at an early stage of development. Even the most advances technologies, namely tidal current and ocean wave still face considerable barriers and many obstacles remain. Research, development and innovation can help overcome those barriers. This review provides an overview over the current state of research in the field of ocean energy. In particular, the authors focus on research beyond technology or technological improvements. This article also highlights

areas where research gaps exists and where future research efforts should be directed to.

**Tidal Power- An Option for Alternative Sustainable Power generation in Bangladesh**

***Tausif Ali, Muhammad Omar Faruk, Sabuj Das Gupata***

**Abstract**

In an energy-hungry world people is seeking for energy to meet up for the future crisis. But oil, gas, coal and other recourses will be finished within 40 years. So, renewable energy is the only solution in order to meet up the future crisis. Solar, wind, wave, tidal, fuel cell, geothermal etc are the renewable energy sources. Among them tidal energy is an old but fficient method. If there is one thing we can safely predict and be sure of on this planet, it is the coming and going of the tide. This gives this form of renewable energy a distinct advantage over other sources that are not as predictable and reliable, such as wind or solar. Rise and fall of tides is more cyclic than random weather patterns. Using this free source we can produce a large amount of power which is very reliable and continuous. The main objective of this paper is show that tidal power may be an alternative solution to meet up recent power crisis

**Tidal Power: An Effective Method of Generating Power**

***Shaikh Md. Rubayiat Tousif, Shaiyek Md. Buland Taslim***

**Abstract**

This article is about tidal power. It describes tidal power and the various methods of utilizing tidal power to generate electricity. It briefly discusses each method and provides details of calculating tidal power generation and energy most effectively. The paper also focuses on the potential this

method of generating electricity has and why this could be a common way of producing electricity in the near future

**Marine renewable energy in China: Current status and perspectives**

***Yong-liang ZHANG, Zheng LIN, Qiu-lin LIU***

**Abstract**

Based on a general review of marine renewable energy in China, an assessment of the development status and amount of various marine renewable energy resources, including tidal energy, tidal current energy, wave energy, ocean thermal energy, and salinity gradient energy in China's coastal seas, such as the Bohai Sea, the Yellow Sea, the East China Sea, and the South China Sea, is presented. We have found that these kinds of marine renewable energy resources will play an important role in meeting China's future energy needs. Additionally, considering the uneven distribution of China's marine renewable energy and the influences of its exploitation on the environment, we have suggested several sites with great potential for each kind of marine energy. Furthermore, perspectives on and challenges related with marine renewable energy in China are addressed.

## 1.4 Objectives of the Study

This thesis displays the physical principles of tidal phenomena considering gravitational effects of sun and the moon semidiurnal, diurnal tide. And how can harnessing this natural phenomenon to produce electricity which called tidal energy, Moreover the mechanism of building tidal power plant included the different tidal power plant feature (tidal barrage and tidal current turbines).

## 1.5 Presentation of the Thesis

This thesis is organized in five chapters; one including this chapter. Chapter two discusses the renewable energy source generally, and its type (Biomass, wind, sun, geothermal and hydropower source) and the technology used to generate energy from this renewable source. Chapter three present the physics of tidal energy by details also it contain the world experience of building tidal power plant by presenting some example of the tidal power station in the world .chapter four illustrate the main feature (operating mode) of tidal power plant (tidal barrage and tidal current turbines) and detailed explanation about tidal energy mechanism and some of the environmental effect. Chapter five contains a conclusion and recommendation for future work. A list of references used in this research is shown at the end of the thesis.

# Chapter Two
# Renewable Energy

## 2.1 Introduction

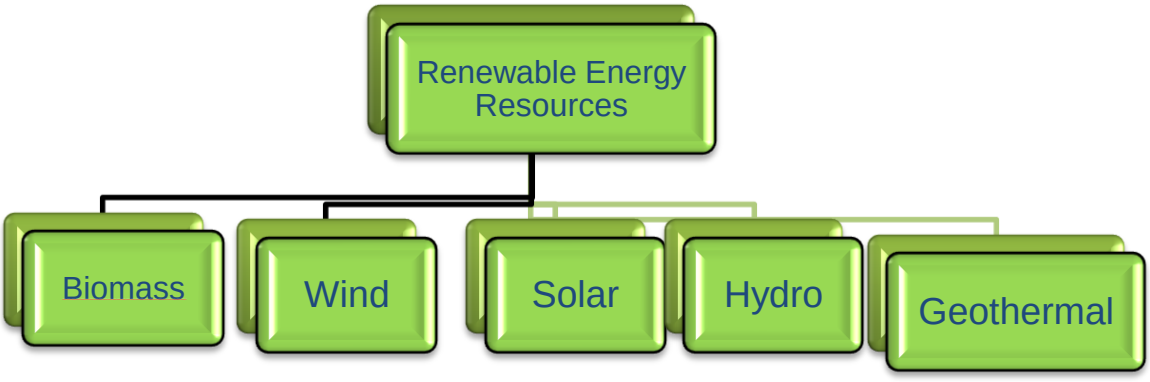
Energy sources conventionally depend on fossil fuel( coal, oil, and natural gas) have clear effect for developing of economic progress, but at the same time damaging to the environment and human health in various form during energy generation and waste disposal by releasing wide range of environmental pollutant such as toxic material, and greenhouse gas (carbon dioxide ) Energy use is responsible for 70% of greenhouse gas emissions[1].which contribute to the climate change, furthermore this source is a non-renewable source ( cannot be replaced once they are used )and will be carried out and depleted over time, so world directed to use new source of energy which is less harmful to the environment called by Green energy source it describes energy produced from renewable sources, most of this source come ultimately from- the Sun [2],it causes little reduced of the earth's resources and negligible emission during energy generation.

Renewable energy refers to energy that flows naturally through the environment on a continual basis [3],its unending source of energy that quickly replenishes itself[4] several renewable energy sources that are in use today direct from the sun (solar radiation energy )or indirectly representing in wind energy, Bio energy, Hydropower. and Geothermal energy, the world's energy demand need to use this sustainable source of energy which is a help to reduce global and local atmospheric emission and create new employment opportunities also offer local re-development .but

for the viability of using renewable energy as source of commercial energy supply must be taken into account the cost of exploiting these resources, renewable energy predominantly provide energy for different areas such as transportation ,electric generation ,water heating and rural energy services. Hydro and biomass sources are the more contribution to the commercial energy use today approximately hydro around 6% and biomass 14% of the global energy consumption [4].

## 2.2 Main Types of Renewable Energy:

There are five type of renewable energy which is shown below:




### 2.2.1 Biomass Energy (bio energy)

Biomass is the term used for all organic material originating from plants (including algae), trees and crops and is essentially the collection and storage of the sun's energy through photosynthesis [1].

Biomass resources are affordable source of energy include agricultural residues , animal residues , urban refuse ,industrial waste sewage sludge,

and energy crops  but the challenge is not the availability so much as the sustainable management and conversion and delivery to the consumer in the form of modern and affordable energy services. The different between Biomass and other renewable energy source biomass stored energy in the form of chemical bond in the matter. Biomass source exists in different state solid biomass, liquid biomass (bio fuel common use as transport fuel) and various biogases.

***Biomass Energy generation***

Different technology used to generate energy from biomass:

Combustion: most common techniques for deriving energy from biomass is a direct combustion either to provide energy directly or to raise the steam into turbine to generate electricity shown in diagram below figure (2.1), like Steam-Rankine cycle uses to generate electricity from biomass on different stage firstly by direct combustion of biomass in a boiler to raise steam which is then expanded through a turbine, the cost of steam-Rankine systems depend on the cost of boiler and turbine.

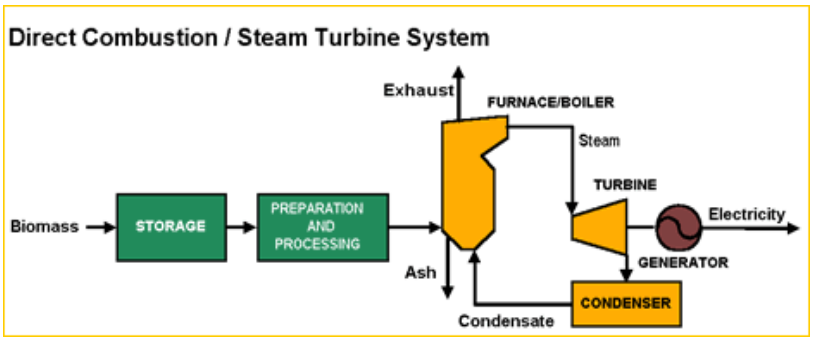



Figure 2.1: Biomass combustion

***Gasification*:** Through a high-temperature thermo chemical process (pyrolytic) can produce Combustible gas from biomass; pyrolytic technology used heat to break down solid biomass into a gas mixture [4].

***Liquid Biofuels:*** Converting solid biofuel into liquid helps to use it as fuel for the transportation sector and it is cheap and can replace on petroleum fuels needs. Main disadvantages of biofuel sources it is heavy compared to energy density and in the combustion process produce air pollution which effect in the environment, but this problem can reduce on modernized biomass energy system. Biomass power generating capacity grew rapidly in the US in the 1980 and currently installed biomass electric generating capacity is about 7 GW, also in California there is a substantial number of biomass power plants in that use agricultural processing wastes as fuel. Resource availability, environmental impacts, and economic feasibility all this factor have greatly affected on the biomass energy project

## 2.2.2Wind Energy

Wind energy is a form of solar energy, it produces when solar energy creates differences of temperature on earth's surface result in movement of air from high to low-pressure regions create a wind. Wind energy is the cleanest energy source thus producing no pollution through energy production; it's a one of the oldest and primary energy source use for milling grain, pumping water and windmills used in the generation of electricity. The basic pattern of wind is set up by the warming of equatorial air, and the cooling of polar air. This provides constant global wind patterns [4] divided into three belt Polar Easterlies, Prevailing Westerlies, and Tropical Easterlies. Faster method for generation electricity by use wind turning aerodynamic blades mounted to a hub which is connected to a shaft to turn a generator sources[2] shown in figure (2.2) oldest electricity

generation wind turbine have three blade but modern turbine typically has two blade only because every blade, as it rotates, reduces the wind speed for the following blades (wind shadow), the most factor affected on the generated power of the wind turbine is wind speed , The wind power increases with the cube of the wind speed.

$$p_{wind} = (\rho * A * v^3)/2$$

Figure 2.2: wind turbine farm

The statistical wind speed distribution, wind directions, turbulence intensities, and roughness of the surrounding terrain this factor effect on the amount of power generation. The Economic success of a wind turbine system is determined by several parameters the most effective parameter is the average wind speed, thus the main disadvantageous of wind energy is where there is little wind, less energy will be made and vice verse, in addition to that we need a lot of turbines to provide enough electricity.

### 2.2.3 Solar energy

Sun represent the origin of renewable energy source, thermonuclear fusion reaction internal the sun produce solar radiation, so it possess enormous energy just 0.1 % of the 75,000 trillion KWH of solar energy that reaches the earth surface ,solar energy can utilize in three ways converting it into thermal energy ,converting it into electricity and photosynthesis[5].
Different type of technologies uses to convert solar radiation into useful form represented into the following categories:

***Passive solar design***

which use to maximize the solar gain from the incident solar ray , buildings are built with heat-absorbing surfaces to maximize solar heating [5]can utilize glazed surfaces which characterize of high transmits to absorbed light but has good insulation properties, energy produced use for heating and cooling the building

***Active solar devices***

Which depend on concentrating the sun's radiation so as to provide heat of sufficiently high quality for space heating, and sometimes electricity generation [4], Solar Photovoltaic and Solar Thermal Technologies are two active techniques used to convert sunlight into a useful form of energy.

***Solar Thermal Technologies***

actively collect, transport, and utilize solar energy to generate heat, most common system focus sunlight on heating an intermediary fluid, known as

heat transfer fluid that then is used to generate steam [ 6] also other solar thermal design can use on space for heating and cooking.

***Solar Photovoltaic***

is a solid-state semiconductor device converts the sunlight directly into electricity operate on the principle of the photoelectric effect (light causes matter to emit electrons) shown in figure (2.3) ,the major application of the photovoltaic modules to power the satellite subsystems in its orbit.

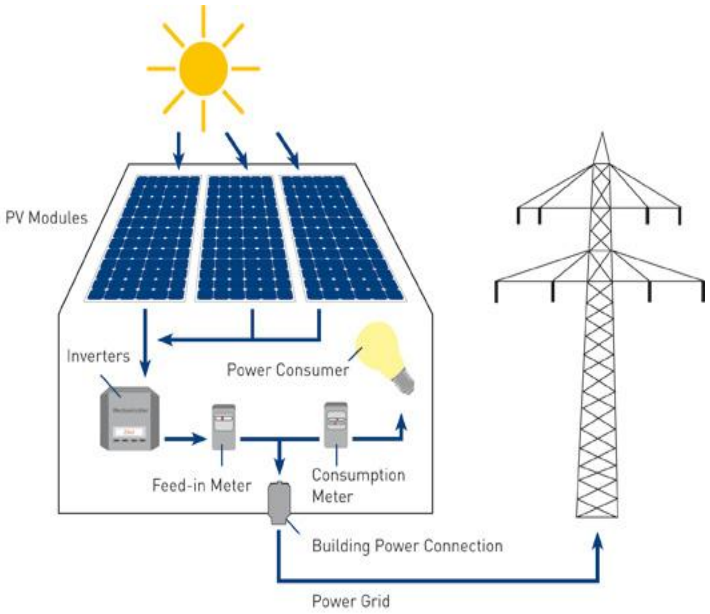



Figure 2.3: Solar Photovoltaic power plant

From another side Production of semiconductor grade ( silicon) produces some environmental pollutants such as sulfur dioxide, nitrogen oxides, carbon dioxide, moreover the process of depositing thin films involves highly poisonous gas silane (SiH4), presenting significant environmental

and health hazards in production, building solar power station has high initial cost to purchase solar panel system and a large area to install a solar system,and it does not operate at night and on cloudy and rainy days.

### 2.2.4 Hydropower

Is the one of the oldest and enormous renewable energy source used for generating electricity, for that it play an important role worldwide for generating hydroelectric power, by converting the energy of flowing water into electricity, there is a several generation method divided into high scale and small scale application for instance of high scale application storing water in high reservoir and releasing water to flow (kinetic energy) through turbine and changed to mechanical energy , the turbine turns the generator rotor which then convert this mechanical energy into electricity shown in figure (2.4)

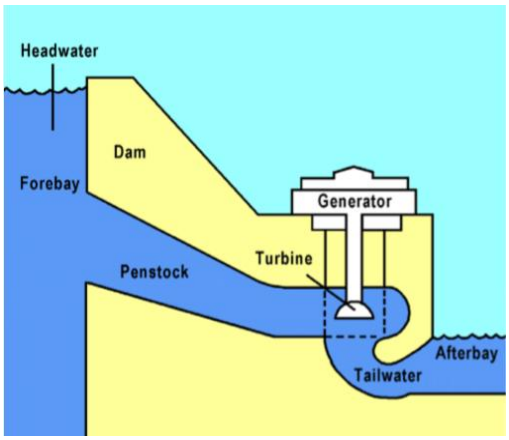



Figure 2.4-a: High scale hydropower plant. Figure 2.4-b: High scale hydropower plant.

For smaller scale there is no storage and turbines draw their power just depend on the flow of water in the "run-of-river, a portion of river water

might be diverted to a channel, to orient the water to a hydraulic turbine which is connected to an electricity generator [9].Wave power and tidal power are two form of hydropower, wave power capture the energy of the ocean surface, by use wave energy converter (WEC) which is device use to convert the kinetic energy of the wave in another form of energy. Tidal power plant converting the energy of tides, where the tide is created by the gravitational effect of the sun and the moon on the earth resulting in movement of the water in the sea, more impact appear in the ocean.

As the wind energy hydropower generally considered as a clean energy source (non-polluting), long live relative to other forms of energy generation, lower cost of, operation and maintenance, but there is some negative environmental impact such as an increase in the sedimentation rate, reduction in biodiversity and fish population.

### 2.2.5 Geothermal Energy

Geothermal energy, the natural heat within the earth, arises from the ancient heat remaining in the Earth's core; create from friction between continental plates slide and decay of the radioactive element. Direct-use applications include heating buildings, growing plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes. The temperature of the inner core of the earth approximately about 4,000C, but only tiny amount of the energy flux reach to the earth surface around 0.06 W/$m^2$ [4] , thus high enough energy can provide useful sources of heat and electricity. Geothermal heat pumps use compressors to pump heat out of the earth or into the earth, it is replaced by the cycle of the season, thus it’s representing renewable sources [2] .The potential source of geothermal energy is the hot  dry rock (HDR) and magma (molten rock) .as shown in figure (2.5) below.

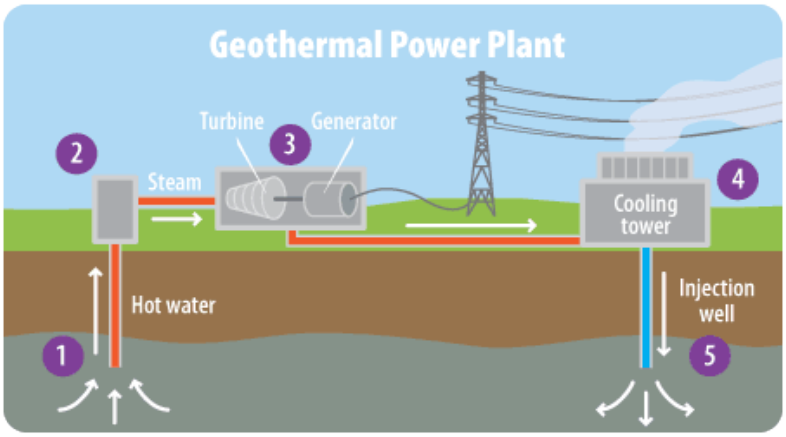


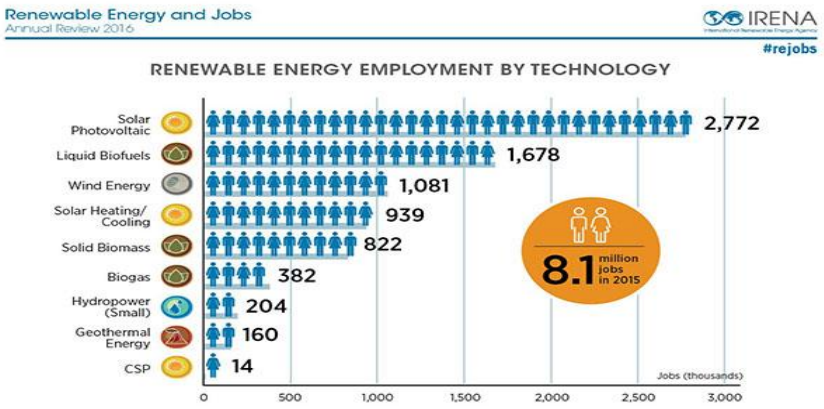

Figure 2.5: Geothermal power plant.

Exploitable geothermal systems occur mainly in the region of high geological activity. A significant geothermal exploration program initiated by the United Nations Development Programme led to the development of geothermal resources in a number of develop in countries. In El Salvador, geothermal electricity generation accounts for 30% of the total installed capacity [4]. The environmental impact of geothermal energy relatively clear and benign source of energy, the most major pollutant concern in geothermal plants is Hydrogen sulfide.

## 2.3 Renewable Energy in The World

California and the Western States have taken the lead in establishing strong renewable energy policies**.** According to a new report from the UN Environment Programme (UNEP) and Bloomberg New Energy Finance (BNEF) , more renewable power capacity was added than other sources and that renewable energy investment was mostly in developing countries

also show that large hydropower plant share of global electricity generation rises to more than 20%. According to the International Renewable Energy Agency (IRENA) report in 2016 for the renewable energy sector employed approximately 8.1 million people as shown in the diagram.



# Chapter Three
# Tidal Energy

## 3.1 Introduction

The earth surface consists of solid material and liquid (rivers, seas, and oceans) material, and it holds and attracts them by the gravity, on the other side the gravitational attraction force between the earth, the moon, and the sun perturb this material on the earth surface, as a result the solid material exposed to small deformation on its structure but clear impact in the liquid material because it's freer to move that cause the tides [6]. The attraction exerted by the moon is too larger than the attraction exerted by the sun according to the small distance between earth-moon with respect to sun-earth distance [11], the earth side nearest the moon has created a bulge of water due to the gravitational force greater than the furthest side. Simultaneously, on the furthest side also bulge of water is created due to the centrifugal pull due to the rotation of the earth-moon system, As a result of the two forces; a resultant bulge is created around the earth [11] as it is illustrated in Figure (3.1) below:

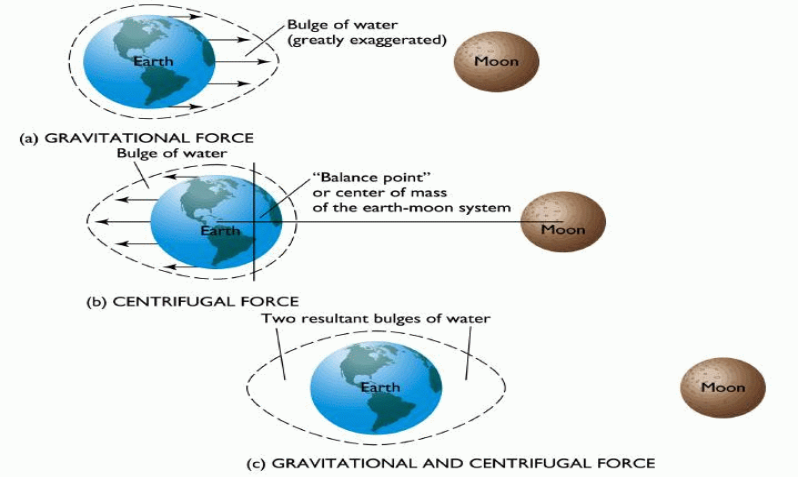



Figure 3.1: Tide phenomena

Tides are the periodic motion of the waters of the sea due to changes in the attractive force of moon and sun upon the rotating earth [12] high tides occur when the sun and the moon are in the line known as spring tides. Conversely, neap tide occurs when the moon and the sun are orthogonal, their gravitational forces pull water in different directions causing the bulges to cancel each other.

Sea level observations show that there are regular water movement on all the shore of oceans, there are two main tidal features of any sea level the first is the tidal range(R) which is the difference in high between two consecutive high and low tides [12], it important to distinguish between tidal range (vertical )and the horizontal movement of the water accompanying with the rise and fall of tides which is called tidal current .the second feature is the period which is the time between one high (or low) level and the next high (or low) level[13],there is two period of the tides diurnal (one high and one low tide per tidal day 24 h) and semidiurnal (two highs and two lows per tidal day12 h25 min), The tides appeared in the large ocean more than small river respect to the water level. Tides were

exploited to produce power called tidal energy defined as the energy dissipated by tidal movements which directly derives from the interaction of the gravitational forces between the seas and the primary astronomical bodies of our system [11], it is a form of hydropower renewable energy source, tidal energy has a significant advantageous over the many forms of renewable energy source because it more controllable and predictable(depend on gravity –not on the weather), it has been used since the 11th Century in Britain and France, also now is taking place in Canada, China, Ireland, Japan, South Korea, Spain, and the united kingdom UK [14].The simplest system for generating electricity from the tides by use a dam across an estuary, Sluice gates on the barrage are opened to allow the tide to flow into the estuary on the incoming high tides, after that water flowing back on the outgo through the turbine system see figure (3.2)below, for instance, if an estuarine basin of area (A) of a dam and the water of density (ρ)runs out through turbines at low tide that the average power produced is:

$$P = \frac{\rho * A * g * R^2}{2 * \tau}$$

Where:

| | | |
|---|---|---|
| P | generated power, R | tidal range |
| ρ | Water density,τ | Periodic time |

Obviously, tidal energy is directly proportional to the square of the tidal range (would generally the tidal range greater than 7 meters).

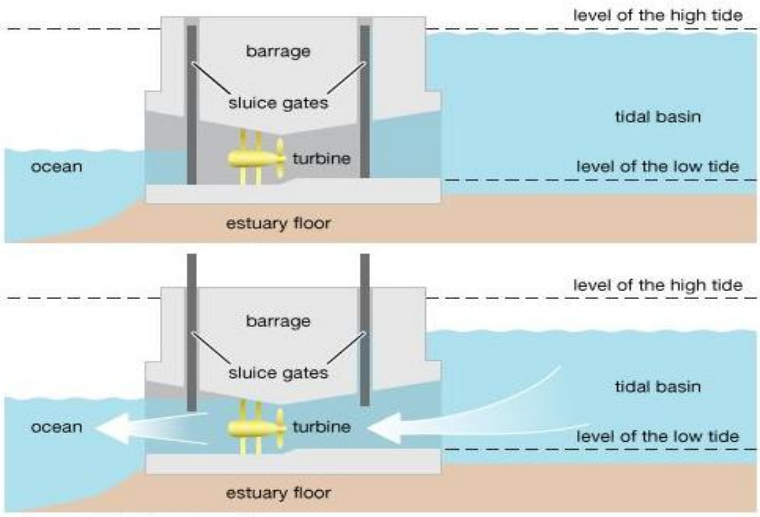



Figure 3.2 Tidal power plants

Tidal power can be classified into two generation method[15]

***Tidal stream generation***

Tidal stream utilizes kinetic energy of tides to produce electricity by spinning a turbine underneath the ocean. operating into two ways which are generating turbine during the low tide and high tide .it is cheapest and less environmental damage than the other generation method, it is being used in France, China, and Korea [16].

***Tidal barrage***

Tidal barrage uses a barrage (large dam )to produce energy from of potential energy of difference in height in low and high tide(similar to the river dam ),the gates are opened to take water in as the tide rises, until reach to the max tide the gate were closed,then while the tide lowers the water release through a barrage turbines, creating energy. It is being

constructed in France and Canada.Generally, above generation method have many ways for power generation:

1) Power generation at ebb tide: by filled the reservoir at flood tide through sluice gates and closed the gate once the tide has reached its highest level and the sea level fall to create sufficient head, then release the water at the ebb tide through a turbine to generate power, for instance of ebb generation plant Annapolis power plant in Canada.

2) Power generation at flood tide: during flood tide, the sluice gates are kept closed. When the tide is high, the water from the sea-side flows into the reservoir via the turbines, thus generating power. But it has less capacity and generates less electricity than the ebb tide generation method, for instance, Sihwa flood generation plant.
3) Two-way power generation: Both incoming and outgoing tides generate power through the turbines require using reversible turbines. For instance, La -Rance is an ebb and flood generation plant [14].

## 3.2 Tidal power station in the world

### 3.2.1 South Korea

Western and southern seaboards of Korea characterized of high tidal range and strong tidal current, then western coast exploit for (sihwa, Garolim and Incheon tidal power plant) and uldolmok tidal current power on the southern coast [17]**.** On December 2004, Commencement of Construction of Sihwa Tidal Power Plant Project equipped with 10 turbines, total Capacity254MW and Annual generation 552.7 GW h, operated by one-way

during flood tides. Figure(3.3) show structure layout [18] Completed on 2009.

Figure 3.3 Sihwa Tidal Power Plant

Garolim tidal power project constructed on 2007-2012 and it is operated by one-way ebb tide .tidal range for 4.7m and basin area of 45.5 k$m^2$, and installed capacity about 480MW. Incheon tidal power project has been established since 2009 and completed on 2015, it is operated by one-way ebb tide, tidal range for 5.3m and basin area of 106 k$m^2$, installed capacity about 1000MW.but Uldolmok tidal current power, utilize triple helical turbine .as shown in figure (3.4)below.

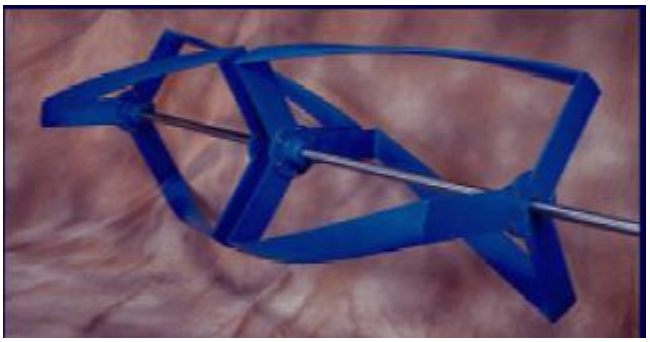


Figure 3.4 Helical turbine

Annapolis Tidal Generating Station installed in Canada since 1980, located between Granville Ferry and Annapolis River, has a capacity of 20 MW, Length of 46.5 m, and depth of 30.5 m [19].

### 3.2.2China

China is one of the leading countries in harnessing tidal energy. It estimated that there are four coastal water exploitable for tidal power (the Bohai Sea, the Yellow Sea, the East China Sea, and the South China Sea) of around 110 GW ,east china sea has largest tidal energy capacity and the average tidal range is (4 – 5) m, and the maximum tidal range (7 – 8) m in these water, It utilize tidal energy resources since 1950 about 52 tidal power plants were built but most of them were deserted returned to many factors (insufficient maintenance and insufficient technology and high cost with less benefit) ,Now only two plants the Jiangxia and Haishan power plants, are in service[20]. The Jiangxia tidal Power Plant is largest one in china began to construct in(1974-1985) and fourth largest one in the world, located at Yueqing Bay, Zhejiang Province, followed after the Sihwa Tidal Power Plant in South Korea, the Rance Tidal Power Plant in France, and the Annapolis Tidal Power Plant in Canada [20].

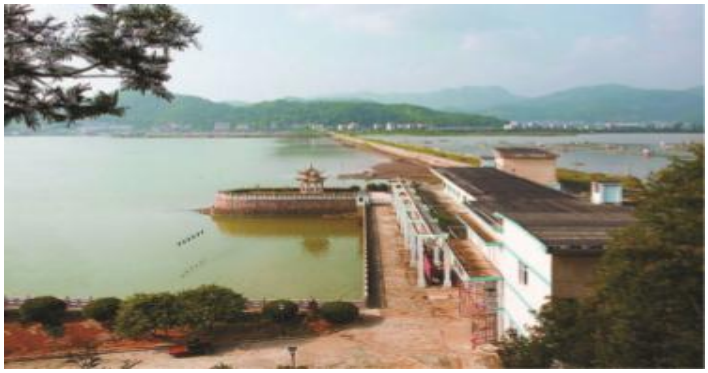


Figure 3.5 Jiangxia tidal Power Plant

The figure (3.5)above shows Jiangxia tidal Power Plant, had total capacity of 3.2 MW, mean tide range 5.08m, and reservoir area (137 $*10^6 m^2$ ) operate on the two-way system.

### 3.2.3France

The first power station in the world is the Rance Tidal Power Station on the estuary of the Rance River in Saint-Malo, Brittany, France and it represents second largest tidal power station in the world. Established on the 26th November 1966 it is currently operated by Électricité de France EDF (French electricity). The plant consists of four main zones(the lock, the plant itself equipped with  24 bulb turbines, the dyke and the six gate barrage),tidal range in France average8.2m to maximum 13.5m, total installed capacity 240 MW(each turbine rated 10MW), it supplies 0.012% of the power demand of France. Giving an annual output of approximately 600 GW h, the barrage is about 750 m [21].

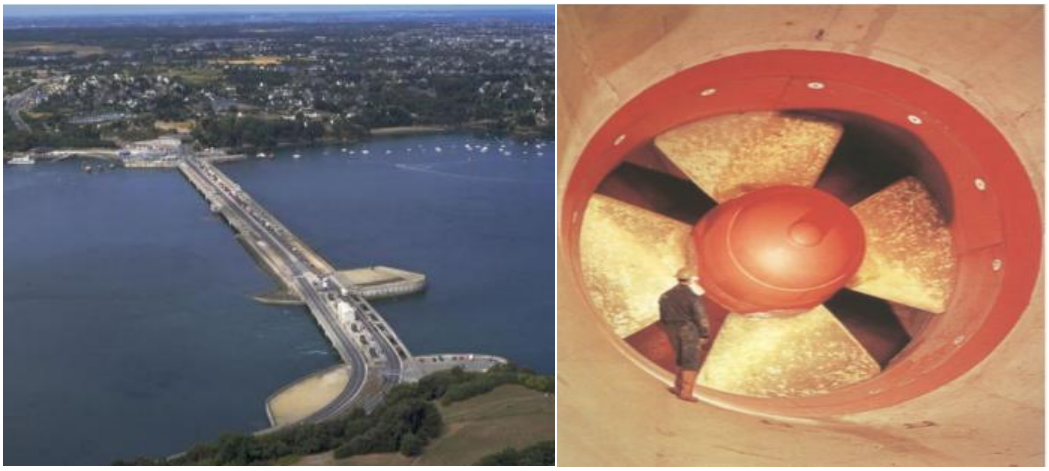


Figure 3.6 la- Rance Tidal Power Station

On the side of environmental impact during the 3-year of construction phases and closing of the estuary, disappearance of marine flora& fauna due to salinity fluctuations, and heavy sedimentation and accumulation of organic matter in the basin the Rance estuary was considered again as richly diversified a new biological equilibrium was reached and aquatic life was flourishing gain.

### 3.2.4Russia

Located on the Arctic shoreline at Russia, providing ecologically safe and reliable power to the Russian electricity grid .

### 3.2.5United Kingdom (UK)

In 2004, Marine Current Turbines (MCT) specified the Narrows of Stanford Laugh, Northern Ireland as their preferred location for the deployment of the Sea Gen tidal turbine [22]. In 2008, Marine current

turbine Stanford Lough Sea Gen power plant using the free stream tidal energy device to convert tidal flow into electricity [23], the device composed of twin 16m diameter rotors connected to a generator through a gearbox, with a rotor system supported on the end of a cross beam [23].the figure (3.7) below shows the Sea Gen power plant.

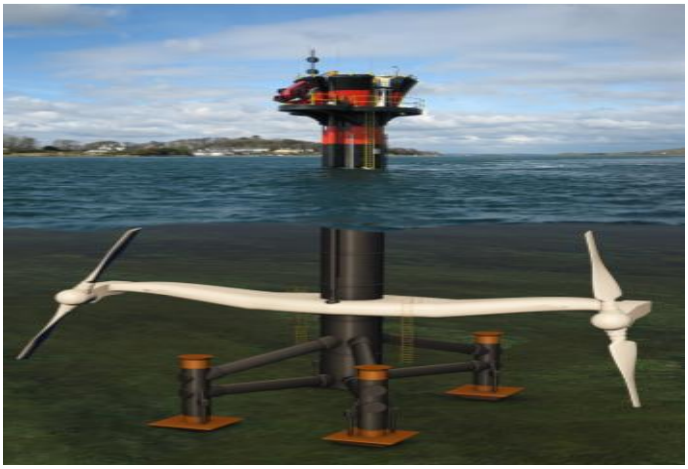
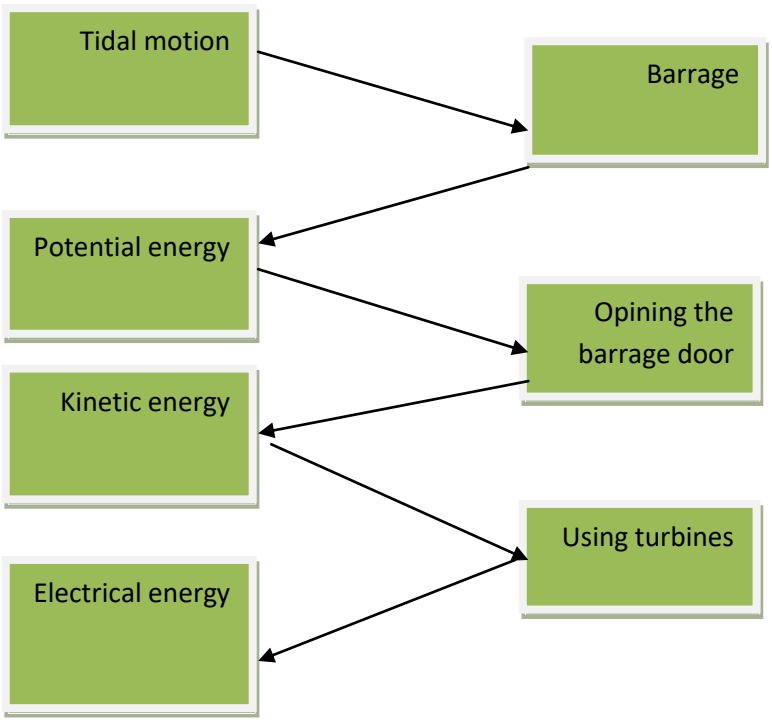


Figure 3.7 Sea Gen power plants.

# Chapter Four
# Mechanism of Tidal energy

## 4.1 Introduction

As previously mentioned on chapter three there are many places in the world have in particularly large tidal ranges such as (Bay of Fundy in Canada, the Severn Estuary between England and east China Sea) [4], That yield to developed different types of tidal power plant around the globe . Mechanism or method of extracting energy from this high natural tidal range and tidal current called tidal power plant . There are main concepts should determine in a design for a Tidal Power Plant (TPP ), and different questions must be answered for example ( what is the type of structure of ( TTP) should be chosen (1 or 2 basins, 1 or 2 directions), What would be the best location to build the TPP, What is the TPP optimal dimensions and specification ,estimation about the main characteristics such as (Capacity ,Energy output , Water levels and water volumes[24].Following the diagram below shows the general procedure of extracting energy from tidal motion :




## 4.2 Energy conversion system

### 4.2.1 Tidal barrage

Tidal barrage represents the oldest technology for extracting energy from tidal range, the basic elements of construct tidal barrage are basin (estuary) which is essential for the successful operation of a tidal power generation plant ,dam(barrage) its wall seal the water stream ,the bottom of the barrage sits on the sea floor and the top above the water level, barrage use to directed the water on the specific orientation turbines, sluices gates and embankment (very large concrete blocks) [11].

***Operation method of the tidal barrage***

The dam can either located at the entrance of the channel or between the main, the function of the embankments is to seal the basin, and the sluices open and close to allow the water to enter and leaves the barrage, water

flow through the turbines, turning an electric generator to produce electricity. There are two designs for tidal power generation plant effect design and double effect design, and single effect design the turbine generate energy in one direction only ,but double design is more complex generating energy on both the incoming and outgoing tides. Such turbines are referred to as double effect turbines which it produces more power compared with single effect turbine.

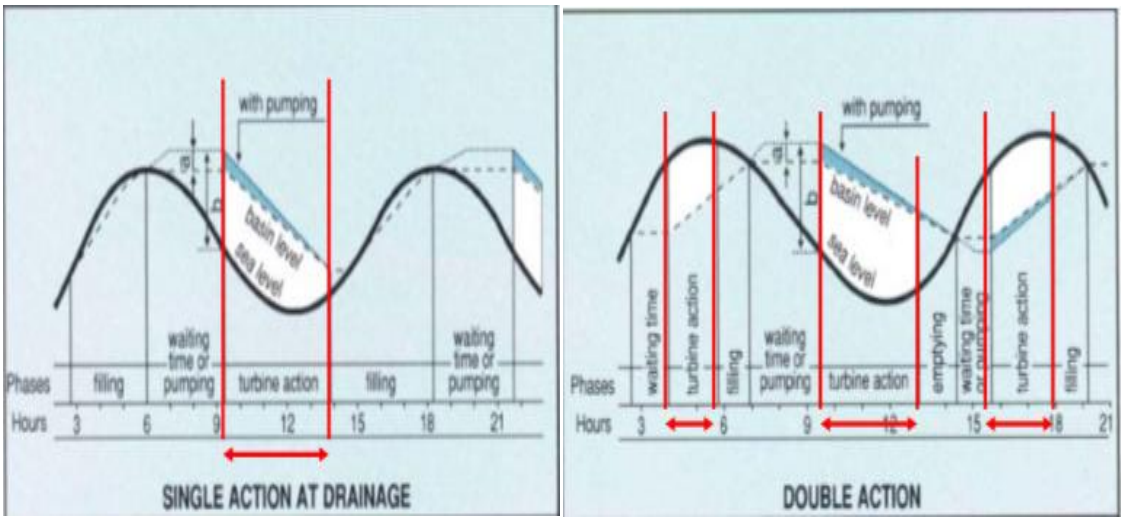



Figure 4.1 Tidal power generation designs

There are numerous of technical evaluation must be decided before establish the tidal barrage plant shows as follow:

***(1)Dam and plant location***

The most important factor in choosing the tidal power plant location is the analyze the functioning of the tide itself, also choose the best place between several options

***(2)Type of structure***

There are two type of structure depend on the basin number, the single-basin system is a simple tidal power plant consists of one basin and a barrage across an estuary as shown in the figure(4.2) below. The system operate during the three operation patterns (ebb generation, flood generation and two- way generation) [11] but in this system just we can exploit energy during part of the tidal cycle

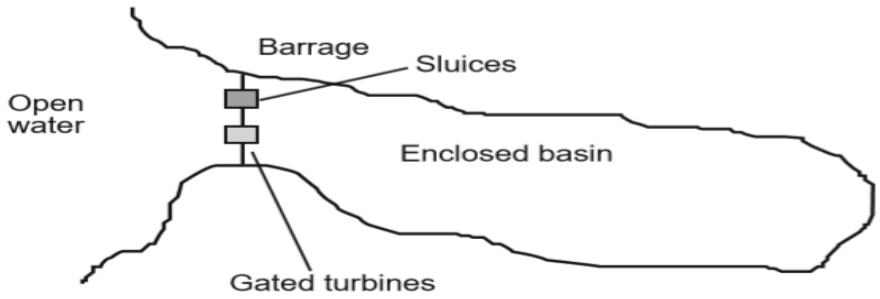



Figure 4.2 One basin tidal power plants

Second type of structure is the double-basin system requires the construction of two basins (high and low one), the main basin is similar to that in the single basin system and the second act as storage element, sluice use for filling the high and emptying the low basin [24], This system is better than the single basin system on the ability of producing electricity on demand and it's relatively constant power output and does not affect by the low-head [11].

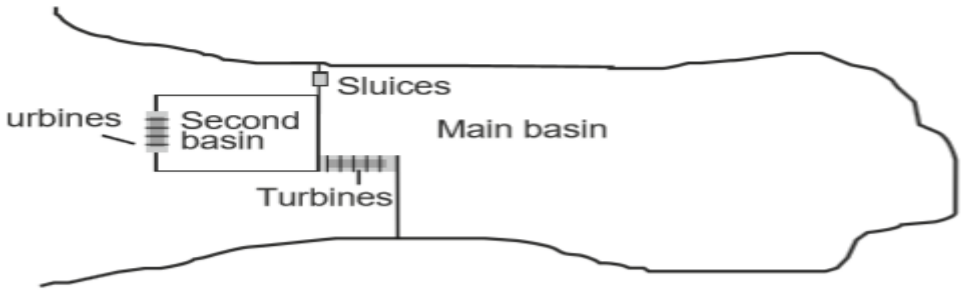



Figure 4.3 Double basin tidal power plants

***(4)Unit power***

According to both aspects of frequency and tidal height the tides quality can estimate. Assuming the tidal range was Δ h and the bay area was A, then the tidal potential energy (E) was calculated from the following formula:

$$E = mg\frac{\Delta h}{2} = \rho\ A\ \Delta h\ \ g\frac{\Delta h}{2} = \frac{1}{2}\rho\ A\ g\ \ \Delta h^2$$

The power from the tidal energy [25]

Assume all the tidal potential energy converted to kinetic energy [25]

$$p = \frac{1}{2}\ m\ \ U^2$$

Where

U represents the tidal current velocity

m represents the water mass

### 4.2.1.1 Types of turbines on tidal barrage

Turbines represent the main element for electricity generation in tidal following barrages, the turbine behaviors mainly determined by the parameters (Head , Flow of water , Throat area of turbine , Rated power output , Turbine efficiency , Runner diameter ,Rotational speed ) [24]Actually there are about 63 types of water turbines are in development such as the operation [25]Choice of turbine type affects on many things conditions and the environmental impact.

Turbine works on the principle of third Newton's Law (For every action, there is an equal and opposite reaction), turbines cannot transform all the potential energy of the water into electric energy but there are three types of losses [24]:

1. Leakage losses: loss of water by passing the blades of the turbines.
2. Hydrodynamic losses (friction along blade and fluid).
3. Mechanical losses

The most common turbine type is a lift –type which is characterized by airfoil blades and the most used in tidal barrage is:

### *4.2.1.1. a Bulb turbines*

It represent the most popular turbine among barrage design, and offer a good solution for low head, the turbine and generator are reversible in work so it can operate in flood and ebb tide , [11] for instance the La Rance tidal power plant in France uses bulb turbine as shown in figure(4.4) below

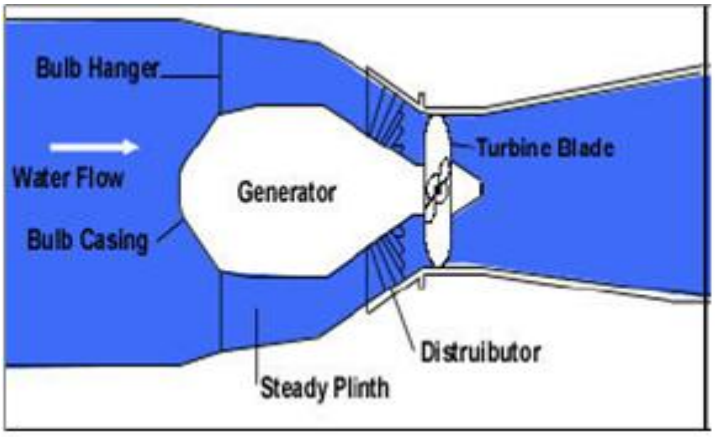



Figure 4.4 Bulb turbine

### *4.2.1.1. b Rim turbine*

In this type, the generator was separated from the turbine. The generator mounted in the barrage and is connected through a shaft that moves with the turbine which located in the water flow, for that its only operate on the ebb tide[11].for instance of real power plant uses rim turbine at Annapolis Royal in Nova Scotia as shown in figure(4.5)below.

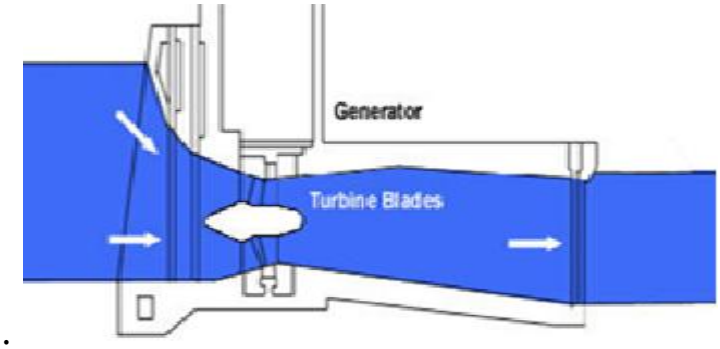



Figure 4.5 Rim turbine

### *4.2.1.1.c Tubular turbines*

The generator is mounted on the barrage at 45-degree angle with the turbine connected by a shaft. It characterized by the ability to change the blades of turbine with respect to electricity demand (small blades generate less power and (vice verse) [11] this type was proposed for use in the Severn tidal project in United Kingdom.

### 4.2.2 Tidal power current generation

Tidal current is the horizontal component of the particulate motion of a tidal wave .Several types of device have been utilized to capture tidal current energy which is called tidal current turbines. This is composed of a number of blades mounted on a hub, a gearbox, and a generator. Tidal current has the same periodicity as vertical oscillations, the ideal kinetic energy is calculated as

$$\mathbf{E = m\,V = \rho\,v\,V}$$

Where

m water mass

V current velocity

The power generated for a mass of water passing through the rotor with a cross-sectional area, A, can express as it follows [11]:

V stream velocity (m/s)

$C_p$ Power coefficient of the turbine

***Operation Method***

The method is similar to the wind energy technology which depends on extracting kintig energy of the wind (air) but on the Tidal current technology it extracts energy from the water current where the water is 832

times denser than air then the water flow speed is much smaller due to different in [11],When the water flows through the blades cause the rotor to rotate the generator which is connected to the gearbox, and transmit the produced electricity through cable.

There are three main type support structures for tidal current turbines which are gravity structure (big mass of concrete and steel attaché to the base to provide stability), piled structure (pinned to the seafloor using steel or concrete beams), and the floating found. [11] As show in figure(4.6) below

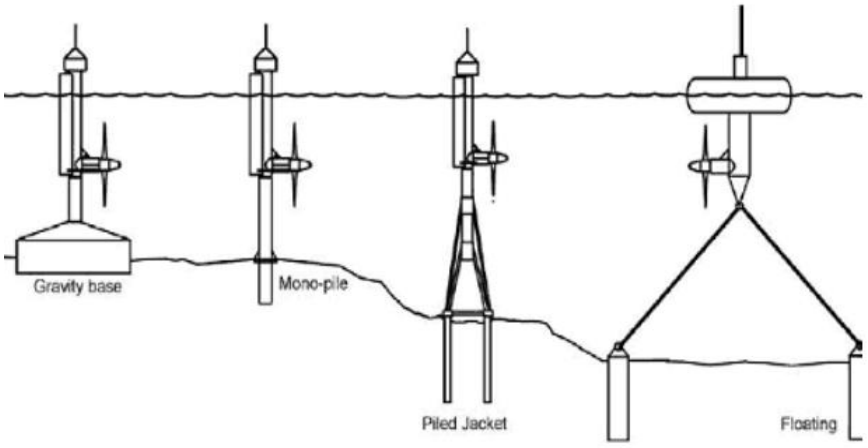



Figure 4.6 Types support structures

The maximum rate of generating power is during spring tide (few days of the month). For this reason, tidal power designer tends to install turbine rated at a lower level than the maximum power available because the potential of capture full energy just during the spring tide.

This technique is known as Electrical Down Rating (EDR) figure(4.7) below show tidal power over the spring-neap cycle[11].

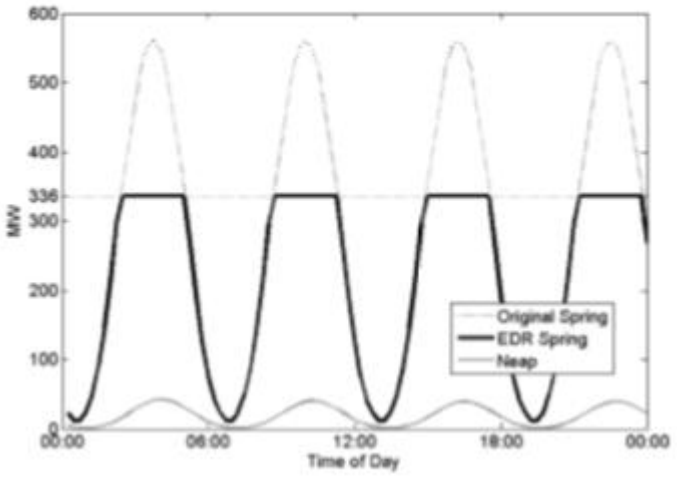


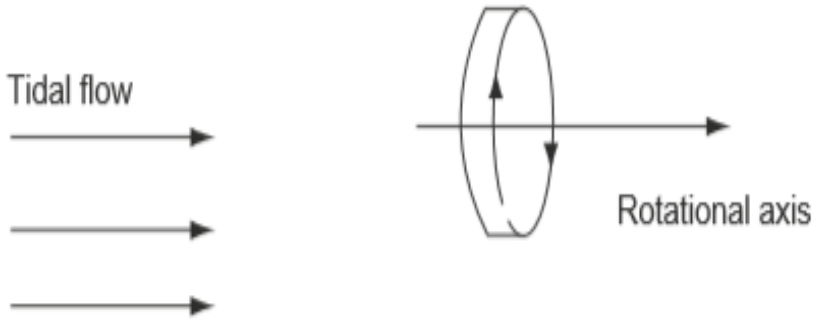

Figure 4.7 Tidal power over the spring-neap cycle

### 4.2.2.1Types of turbines on tidal power current generation:

There is two main type horizontal axis and vertical axis current turbine

#### *4.2.2.1.a Horizontal axis tidal current turbine*

The feature of a horizontal axis turbine is consisting of turbine blades parallel to the direction of the water flow on a horizontal axis, then the rotation axis is parallel to the direction of water flow as shown in figure below [4], large rotor diameter, and high TSR (tip speed ratio) [25].The turbine arranged in a row, similar to some wind farms and the ideal locations for tidal turbine farms are close to shore [11]




The most famous installation is the dual horizontal axis turbines MCT (Marine Current Turbines) made by Siemens[ 25] for instance of real project Sea Gen with dual rotors in Strangford Lough, Northern Ireland shows in figure(4.8) below

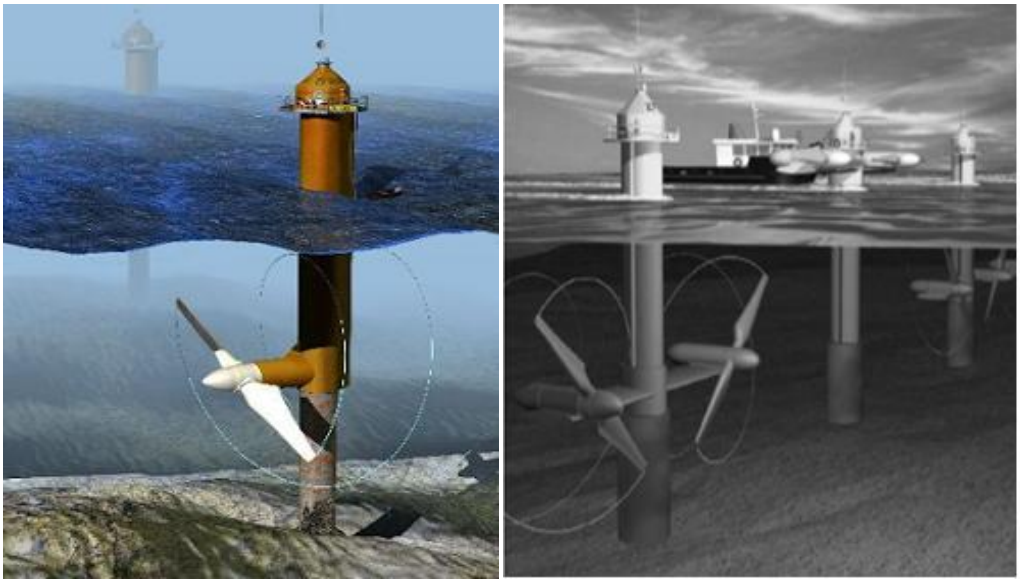


Figure 4.8 : Horizontal axis turbine

### *4.2.2.1.b Vertical axis tidal current turbine*

The vertical axis turbine characterized by turbine blade rotates on a vertical axis which is perpendicular to the direction of the water flow as property of vertical axis design it shown in the figure below (4.9) [4]. The permits the harnessing of tidal flow from any direction and the blades can easily build and easily to increase their span too. For instance of vertical axis turbine project the Kobold turbine and the Blue energy project [11].

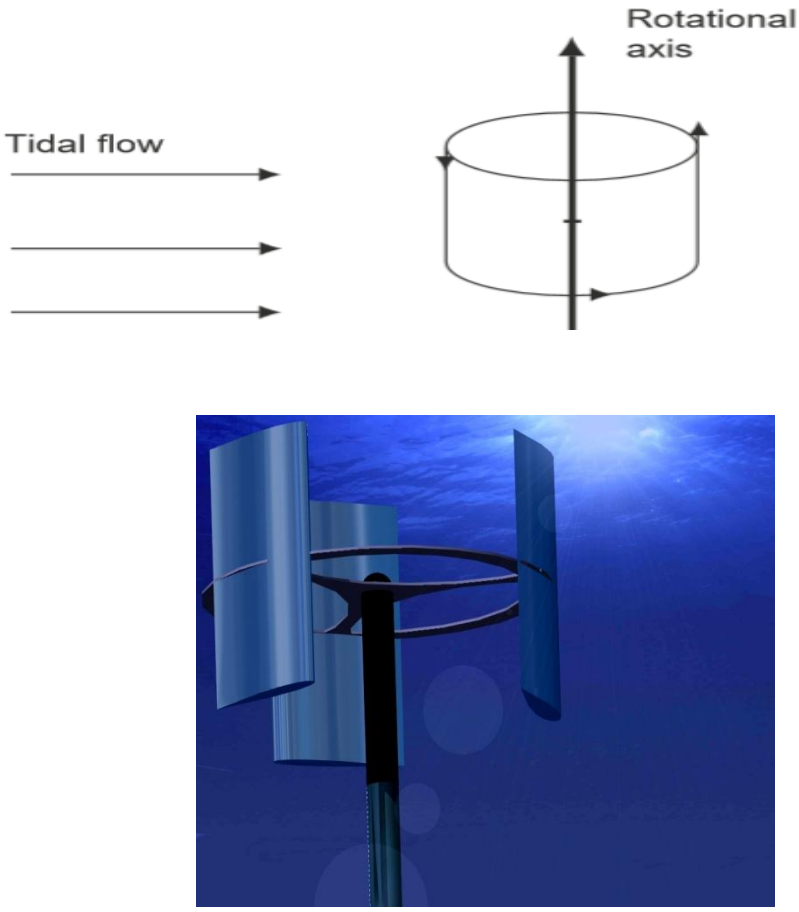



Figure 4.9 Vertical axis turbines

Both in the vertical axis turbines and in horizontal axis the rotation speed is very low, horizontal turbines have slightly higher efficiency than vertical turbines

## 4.3 Tidal power plants and environmental

Main environmental problems caused by large-scale tidal barrage:
1) Barrages cause a barrier for naval traffic, which allows some traffic, but it is a slow and costly alternative to free access to the ocean.
2) Also, it impedes fish migration.
3) Morphological problems (The balance of sediment transport can be disrupted) [24]
4) The change in flow, depth, and sea waves can be expected to change many other ecological characteristics [6].

## 4.4 studies of construct tidal power plant in Sudan

Developing renewable energy in Sudan represents a real addition to the energy and provides electricity demand, tidal power is considered to be the highest priority.

Calculation of tidal range and tidal type in red sea port sudden it found that the average tidal range between (0.97-1.2)m and diurnal tide is dominate [27] (tidal energy is directly proportional to the square of the tidal range) ,Comparison between tidal range and the installed capacity of some tidal power plant in the world

Table show the spesification of tidal power plant in souh korea and china:

| Tidal power plant | Location | Specification | Installed capacity |
|---|---|---|---|
| Garolim tidal power project | South Korea | Tidal range 4.7m basin area 45.5 $km^2$ | 480MW |
| Incheon tidal power project | China | tidal range 5.3m basin area 106 $km^2$ | 1000MW |

.

The problem that hinders establishment of tidal power plant in the red sea in Port Sudan because it located close to the amphidromic point where the tidal range is almost zero [27]

# Chapter Five
# Conclusion and Recommendation

## 5.1 Conclusion

Tidal power is a renewable energy source its distinction of being more predictable and cleaner energy source associated with the environment, therefore it becomes one of the more promising energy sources But the main obstacle behind development tidal power plant is the high capital cost, although plant has an average life in the range(75-100) years. Construction of tidal power plant bring huge and several benefits while operating such as allow of transportation between the coast (as a bridge) ,it can act as a barrier against the flood and may affect on the aquaculture, on the other hand, tidal power plant causes change on the estuary ecosystem. And some of the unpredicted effects occurred over long -term, all in all, the negative environmental impacts of tidal power plant are probably much smaller than those of other sources of electricity .

Comparison between two main tidal features tidal barrage and tidal current turbine, utilizing tidal current turbine much favored than tidal barrage to avoid most of the environmental impact. Tidal current devices have a lesser impact on the environment than tidal barrages.

## 5.2 Recommendation

According to a lot of efforts and studies in the Red Sea Port Sudan to evaluate the tidal constituents concluded that due to the low tide elevation and small tidal signals it’s hard to generate enough power .This thesis

proposes to use model to measure the tidal current velocity factor and estimate its efficiency of generating power.

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