INTRODUCTION:

The ocean tides are periodic rise and fall of ocean water level occurring twice in a lunar day. Duration of a lunar day is of 24.83 hours. Time between consecutive high and low tide is 6.207 hours. Tides occur due to gravitational forces of the moon and sun on ocean water and affected by the spinning of the earth around it axis and relative positions of the earth, moon and the sun. The distance between the sun and earth is much more than the distance between the moon and the earth. Hence the moon has greater contribution in formation of the ocean tides.

The ocean tidal energy is due to the difference in ocean water level between high tide and low tide. During high tide the level of water increases with reference to low tide level. The potential energy is higher during the high tide than that of during low tide. The potential energy difference during high and low tide is the tidal energy. *Tides are periodically renewed, hence tidal energy is renewable.* Tidal energy is of the form *of Hydro – energy* with every tide.

The rise and fall of water is maximum near sea shore and river mouth i.e. bays. River mouth locations may be used for the constructing tidal power plant.

The difference in water level between high and low tide is called *Tidal range* ***R***. Tidal range varies widely from one location to another from 0.25 m to 10 m. and is not favorable for the conversion. Only about 200010^9 MW cab be used.

Fig 1. Shows schematic of a simple tidal energy conversion plant.

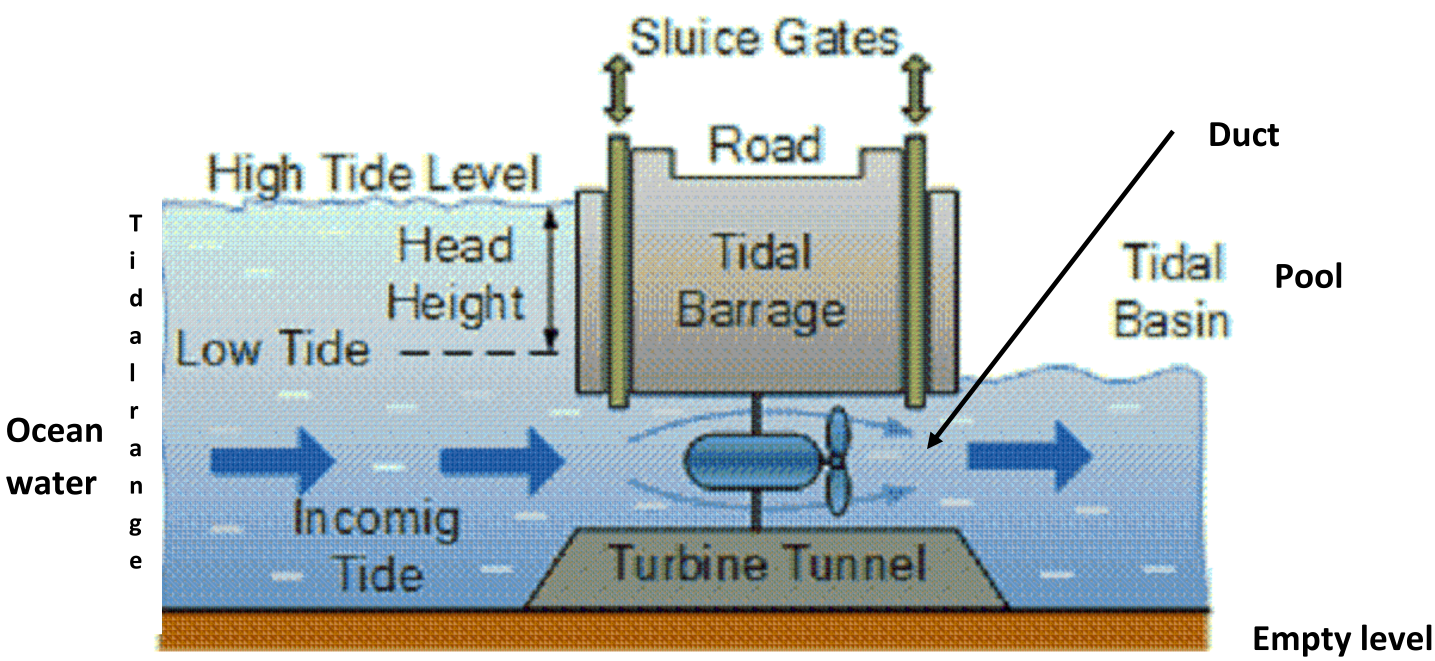


Fig: 1

Tidal power plant is similar to Hydro electric power plant technology a barrage is built across the tidal path. Hydro turbines – generator units are installed in the tunnels within the barrage. Water flows from ocean to the pool during the high tide and gets controlled in the pool to the high tidal surface level.

During low tide the water level in the ocean decreases but the water level in the pool remains high. The energy is stored in the form of head of water in the pool. During low tide water stored in the basin (pool) is released into ocean through the ducts and the turbines rotate. Power is generated only during the low tides in the ocean. This type of the tidal power plant is called single effect tidal power plant.

In a double effect tidal power plant reversible turbine generator units are installed within the duct in the dam. During high tide water flows through the duct from ocean to the basin. Turbines are rotated in forward direction. During low tide water stored in the pool is released into the ocean through ducts and turbines can rotate in reverse direction. Power generated during high tide and low tide. This type of power plant is called double effect tidal power plant. The tidal scheme may be of single pool or double pool or multiple pools.

<u>TIDAL RANGE R:</u>

The difference between successive high tide and low tide water level is called tidal range R.

Tide range R= (High tide level) - (low tide level) m

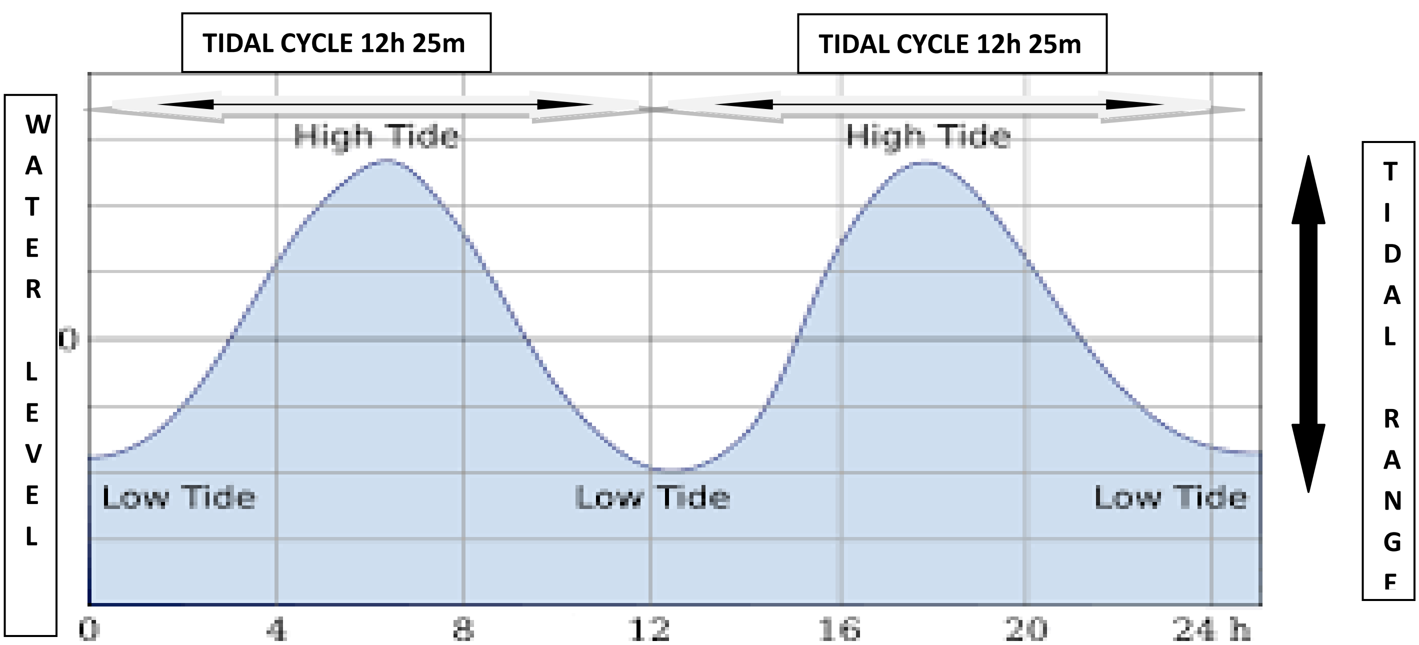


Fig 2.Tidal characteristics (Diurnal Characteristics) for one lunar day

Fig 2 shows the tidal characteristics for one lunar day. This characteristic also refers as diurnal characteristics. It includes two low tides and two high tides for one rotation of the moon around earth. The tidal curves are approximately sinusoidal. The diurnal tide mean tide is same as the diurnal tidal range. Tidal range amplitude varies widely depending upon geographical location, tidal current of the ocean bed, depth of the oceans, distance from the cost etc. Tidal current is the flow of water during changing tidal level.

Tidal range at the same location is not constant but varies with lunar days in the month. Lunar month is of 29.5 days. Relative position of the sun, the moon and the earth the tides are classified as either ***Spring tides*** or ***Neap tides***. Tidal range is maximum on full moon and new moon and such tides are called ***Spring tides.*** The tidal range is minimum on the first quarter and third quarter moon and is called ***Neap tides***.

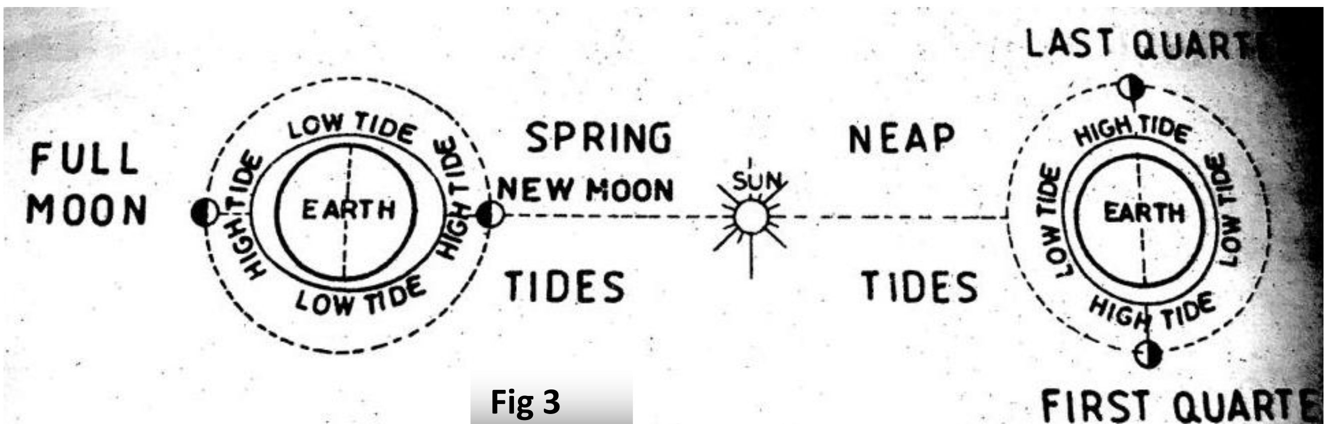


Fig 3

HIGH AND LOW TIDES:

Fig 4 shows record of daily and monthly tides in complete lunar month. Monthly cycle of two maxima and two minima in one lunar month is due to changing position of the moon and the sun with the revolution of the moon around the earth.

Fig 2 shows the cycle of the tides in one lunar day and is due to the rotation of earth about its axis produces two crests (high tides) and two ebbs (low tides). Tidal range has daily variations and superimposed on a monthly variation.

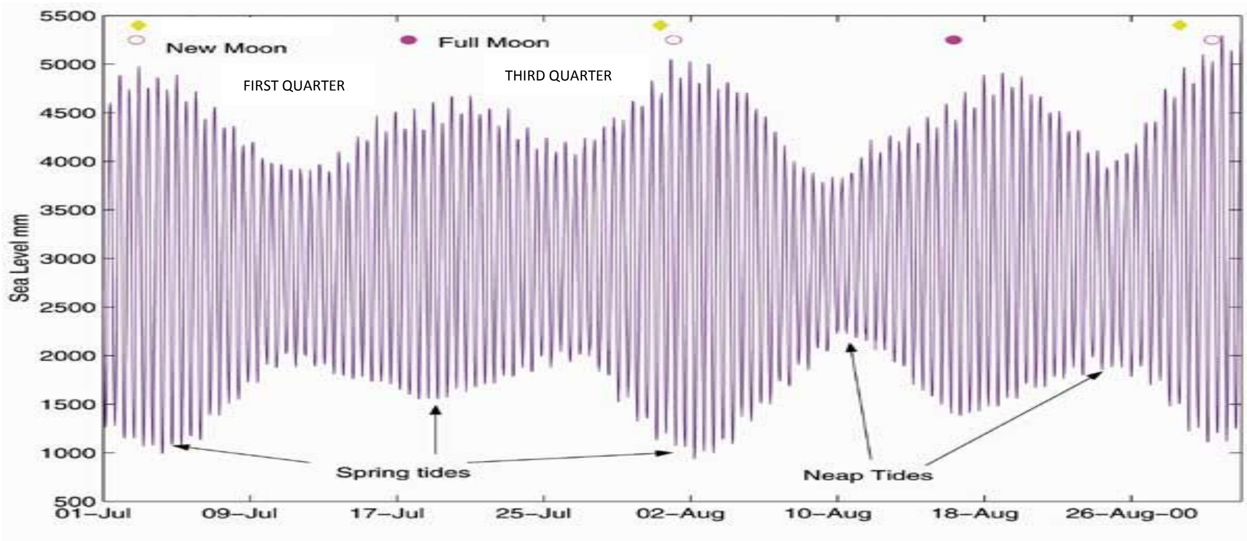


Fig: 4

TIDAL ENERGY CONVERSION:

Tidal energy is converted into mechanical energy by hydro turbines. The hydro turbines drive the electrical generator rotor. The electric energy is thus produced from the tides.

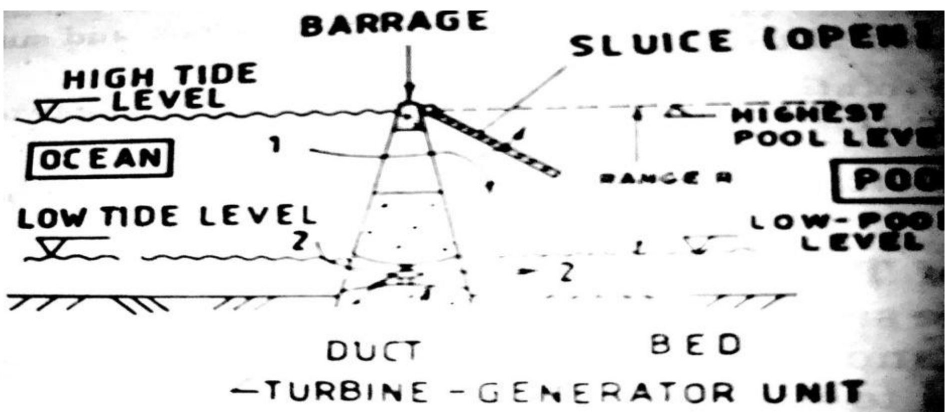


Fig: 5

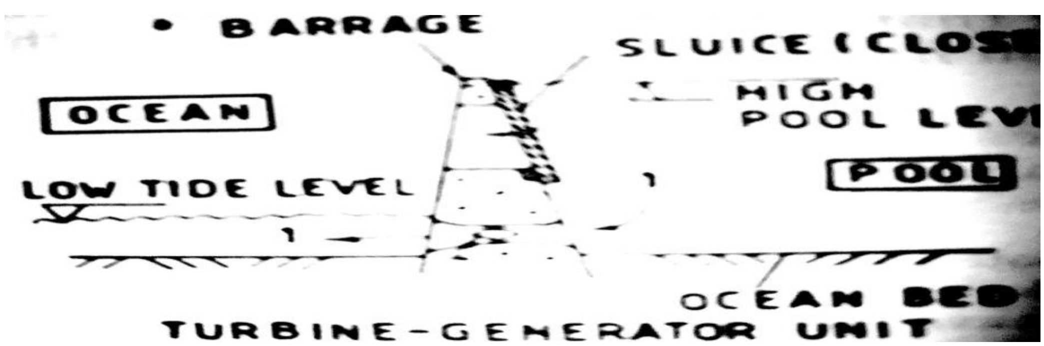


Fig: 6

Fig. 5 shows the tidal range, Head, fillling the basin (pool) from ocean water during high tide. Fig. 6 shows tempthying the basin water into ocean during low tide. First we calculate tidal energy conversion for one tide in a single effect tidal power plant shown in Fig 7 for the area of the pool A.

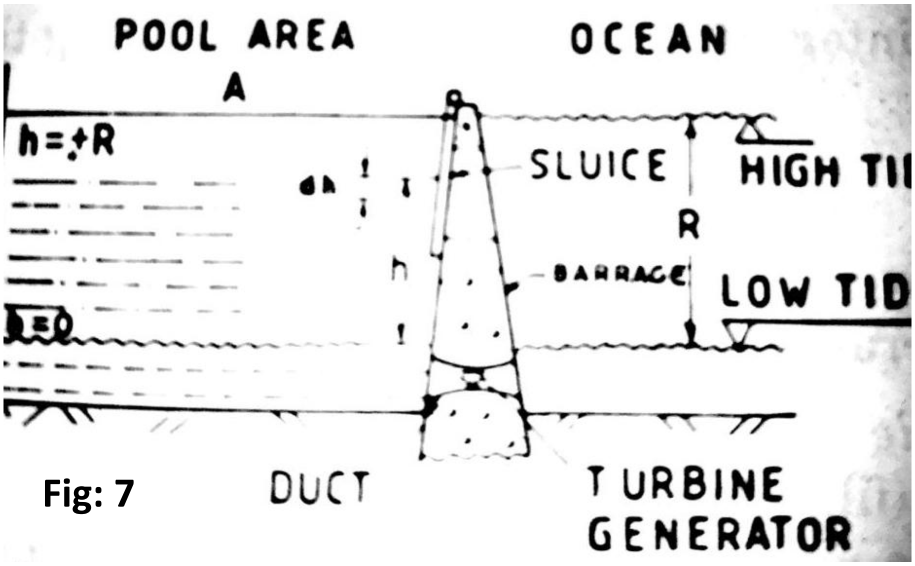


Fig: 7

In a single effect power plant the water is filled in the pool during high tide. The stored water flows from the pool to the ocean during low tide and drives the turbine generator. In single effect power plant power is generated only while emptying the pool.

If R is the tidal range, A is the area of the pool, h is the head of water, D is the density of water ($1025 g/m^2$), m is the mass of the water flowing through turbine, t is the time for which water is flowing through the turbine, g is the acceleration due to gravity(9.8m/s), then work done dW for the given time dt during the flow of water from pool to ocean is equal to the change in potential energy due to change in mass dm of the water and is given by equation

$$dW = R\, dm\, h \qquad \text{(in joule)} \qquad 1$$

Mass of the water flows through the turbine for the give time t is

$$dm = -\ D\, A\, dh \qquad \text{(in kg)} \qquad 2$$

Equation 1 rewritten as

$$dW = -\ g\, D\, A\, h\, dh \qquad \text{(in Jules)} \qquad 3$$

The total work done by the turbine by emptying the pool from height Rm to 0m is

$$W = \int_o^R dW$$

$$= - g D A \int_o^R h\, dh$$

$$= - g D A (h^2/2)_R^o$$

$$= g D A R^2/2 \qquad \text{(joules)} \qquad 4$$

Equation 5 gives the work done by water while emptying the pool of range R and area A per tidal cycle possible from single effect scheme.

With double effect tidal power plant the tidal energy converted into electrical energy during both the tides i.e. during high tides and during low tides. The work obtained per tidal period is twice that of single effect tidal power plant.

For double effect tidal power plant the work done by the turbine for the pool area A and tidal range R is

$$W = g D A R^2 \qquad \text{(joules)} \qquad 5$$

In equation 4 and 5, g acceleration due to gravity (9.8m/s) and D density of ocean water ($1025 g/m^2$) are fixed amount, hence work done by the turbine while filling or emptying the pool is proportional to A and R^2. Equation 4 & 5 we can conclude that,

1) Large the pool area and long barrage is necessary for more energy and power from the plant. This increases major capital investment. So pool area cannot be increased beyond certain range once the tidal power plant is constructed pool area A is fixed and cannot be changed.
2) The tidal energy is directly proportional to the square of the tidal range at the location of the plant. Hence obtaining more energy tidal range must be high enough (R>2.5m).
3) Equation 4 give the energy in one tide range R and the work done by the turbines during the discharging of water from pool area to ocean. The energy is converted during the each low tide generation period.
4) Equation 5 gives the energy conversion in one tidal cycle for a double effect plant. Energy is converted during filling and emptying the pool by rotating turbine in forward and reverse direction respectively.
5) During every filling and every emptying of pool, certain energy is converted. The cumulative energy over a year is quite significant.
6) When pool is not getting filled or emptied energy conversion is zero. Certain energy is essential for such periods.

TIDAL POWER:

Power is time rate of energy conversion or time rate of work.

Power = [work/time duration of work]

For a single effect turbine power plant

P = W/t

For a single effect tidal power plant

P = [gDAR2/2t]   in watt   1

Equation 1 gives power rating of the plant based on duration time t. For the rest of the time the power generation is zero.

Similarly For a double effect turbine power plant power rating is

P = [gDAR2 /t]   in watt   2

From plant of same power rating is converted during filling and emptying pool.

The moon follows an elliptical path around the Earth in its monthly orbit, and the Earth follows an elliptical path in its yearly orbit around the sun. This means that, at times, the moon and the sun are closer to Earth. Once about every 28 days, the moon reaches a 'perigee,' its closest point of approach to the Earth. This is the point at which the gravitational pull of the moon is strongest. During these periods there will be an increase in the average range of tides. Conversely, about 14 days following the perigee, the moon reaches an ‘apogee’, its furthest point of approach to the Earth. This is the point at which the gravitation pull of the moon is weakest. During these periods there will be a decrease in the average range of tides.

OCEAN ENERGY TECHNOLOGY

INTRODUCTION TO ENERGY FRAM OCEAN:

The ocean and huge lakes and bays are huge reservation of various useful and renewable energy resources. World’s total estimated ocean energy reserves are about $130X10^{6}$MW. However, only small fraction can be recovered economically.

The interest in ocean energy has been received after the energy crisis of 1973. The important ocean energy conversion technologies under active consideration are

i) Ocean biomass energy

ii) Ocean wave energy
iii) Ocean geothermal energy
iv) Ocean tidal energy
v) Ocean chemical energy
vi) Ocean thermal energy
vii) Ocean salinity Gradient energy
viii) Ocean wind energy

Ocean biomass energy refers to aquatic organic matter such as algae kelp, and water hyacinths grow in ocean, aquatic vegetation, marines' animals and fishes etc. Ocean biomass may be converted into methane rich biogas by wet anaerobic digestion process. Alternatively, biomass may be dried and burnt.

Ocean wave energy refers to the waves of water from ocean shore. Ocean waves occur due to the rotation of the earth and the winds over ocean surface. Waves have an interval of 4 to 12 seconds and crest of few centimeters to about 10m. Locations having waves with crest height of 3m and above have higher energy density. Ocean wave machines are installed on floating power plants or on store power plants. The rotor of the wave machine is rotated by wave energy. Wave machine drives generator rotor or pumps water to the reservation at higher level.

O*cean geothermal energy* refers to geothermal energy available from off shore geothermal fields.

Ocean tidal energy refers to the hydro energy in ocean tides. Ocean tides occur due to gravitational attractive forces from sun and moon. The level of the ocean water rises periodically during the high tides and drops during low tides. The difference head of water during high and low tide is used for rotating hydro turbine generator units installed within barrages electrical energy is obtained. The time span between high tide and next low tide is 6h25m.

Ocean chemical energy refers to the chemical energy in ocean water contains Sodium, Chlorine, Oxygen, iodine etc. Ocean chemical energy is converted to secondary energy forms by photochemical process, fuel cell, Photo biological conversion processes. Hydrogen and Nitrogen are obtained from these from three processes. These are used as fuels and oxidants in fuel cells. Electrical energy is obtained from fuel cell.

Ocean thermal energy refers to the thermal energy acquired by the ocean water from solar radiation. The warm water from upper levels of ocean is pumped through heat exchangers. Thermal energy is extracted and converted to electrical energy by steam turbine generator or vapor turbine generator. Cold water from the bottom of the sea is used for the condenser.

Ocean salinity gradient energy is the type of chemical energy. The salinity of ocean water differs from that of river water. The difference in salt concentration between two fluids can be used for generating electrical directly from the ocean water (commonly fresh and salt water, e.g., when a river flows into the sea).

Ocean wind energy refers to off shore wind energy resources over ocean.

Ocean nuclear energy refers to nuclear resources

Energy from ocean currents refers to hydro energy in water currents through the large rivers terminating in the ocean. The currents have kinetic energy which converted into electrical energy by turbine generator.

TYPES OF OCEAN ENRGY	TOTAL WORLD POTENTIAL MW	PRESENT INSTALLED CAPACITY
THERMAL	10,000,000	NEGLIGIBLE
WAVES	5,000,000	NEGLIGIBLE
TIDES	200,000	250
CURRENTS	50,000	NIL
SALINETY GRADIENT	3,540,000	NIL
OFF SHORE GOE THERMAL	30,000,000	NIL
BIOMASS RESUOUCES	800,000	NEGLIGIBLE
URANIUM RESOURCES	80,000,000	NEGLIGIBLE
TOTAL WORLD POWER CURRENT UTILIZATION OF ALL TYPE	129,590,000 MW	1000MW

OCEN ENERGY RESOUCES:

The oceans cover about 70% of earth's surface, are great reservoirs of various forms of energy resources.

1. OCEAN THERMAL ENERGY

The ocean is the largest solar energy collector on Earth. Solar radiation is absorbed by the ocean and lake water. The thermal energy is stored in the ocean water at low temperature (up to 27^0C). At depth below 1km, the water temperature does not exceed about 10^0C. The solar energy absorbed by all the oceans in the world is estimated at 2000EJ/yr ($E=10^{18}$). Only a small fraction of this energy is recoverable (1EJ/yr).

Average solar energy absorbed by the ocean is approximately 3 X 10^6 kJ/m^2 per year. The equivalent average power density is 95 W/m^2. The temperature in upper ocean water is about 27^0C and at lower depths about 10^0C.

Ocean thermal energy converter (OTEC) converts ocean thermal energy to electrical energy. The total potential of ocean thermal power plants' in the world is 10 $X10^9$ MW. However, due to heavy cost of technology only a small fraction of about 5000MW may be recoverable in near future. Present use of OTEC is negligible.

OTEC processes are of two types

1) Flashed steam, *steam turbine cycle OTEC* plant using steam water as working fluid (open cycle OTEC). The name 'open cycle' comes from the fact that the working fluid (steam) is discharged after a single pass and has different initial and final thermodynamic states; hence, the Sow path and process are 'open.' The essential features of an open cycle, Warm ocean water is directly flashed to steam and steam turbine generator delivers energy.
2) *Binary cycle OTEC* plant based on working fluid of low boiling point (NH_2, Propane) and special turbine (closed cycle OTEC). Working fluid that would evaporate at the temperature of warm sea water. The vapor would subsequently expand and do work before being condensed by the cold sea water. This series of steps would be repeated continuously with the same working fluid, whose Sow path and thermodynamic process representation constituted closed loops hence, the name 'closed cycle.'

In both types, cold water from bottom of ocean is used for condenser.

Major problems in OTEC plants are:

- Corrosive sea water
- Large size of heat exchange and large volumes of sea water to be circulated.
- High installation cost.
- Low temperature of ocean water, low efficiency of thermal cycle.
- High cost of electrical energy obtained from OTEC plants.
- OTEC theory was first developed in the 1880s and the first bench size demonstration model was constructed in 1926. Currently the world's only operating OTEC plant is in Japan, overseen by Saga University.

OCEAN WAVES ENERGY:

Ocean waves have hydro energy with a period of 4 to 12 sec. and level of few cm to about 10 m, sites having crest of 3m to 4m and above are favorable. A typical 2m wave with 6 sec. period has energy density of about 5000j/m^2 and power density of about 800W/m^2.

Total wave energy potential of world is about 1000E/yr. Out of this only a small fraction is recoverable. The potential of wave power plant in the world is 5000000MW. Salient aspects of ocean wave energy are

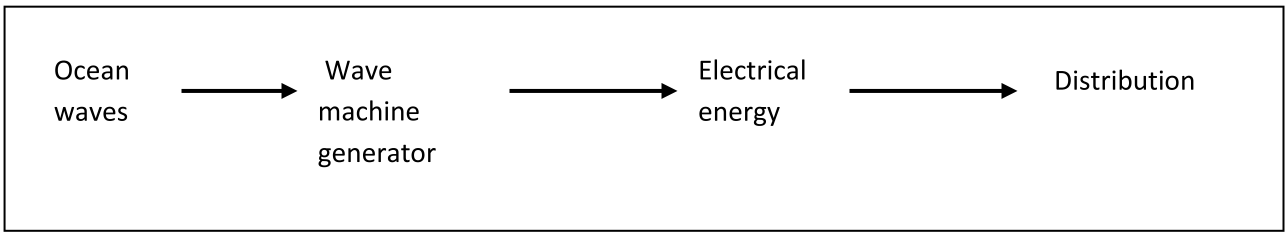
- Power density of ocean waves is low.
- Ocean power plant off shore have difficulties such as corrosion due to saline water, obstacle to navigation hostile whether condition, high cost of power transmission from the off shore to the land based load center.
- Commercial ocean wave plants have not built yet.

Merits of ocean wave energy are

- Renewable energy source
- Relatively high energy density and power density compared to solar and wind.
- Waves are continues during day and night throughout the year.

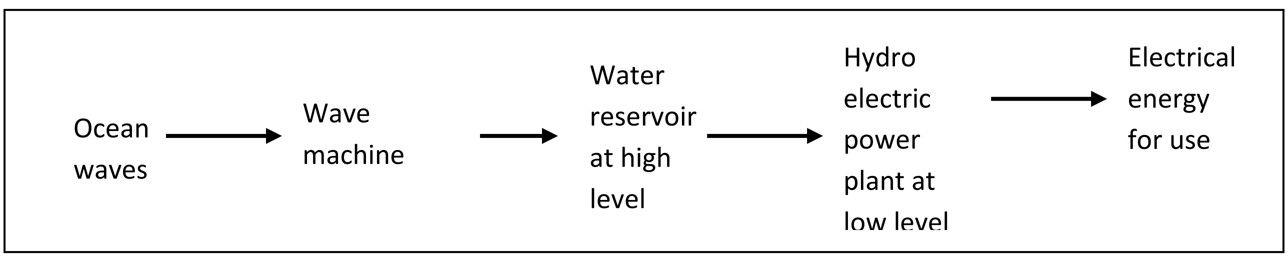
The energy routes if ocean wave energy conversion are of the two types

1.



<u>Alternatively</u>

2.



Wave energy conversion plants are located at sites where wave heights are more than 1m and period less than 6 sec. Western cost of India has several suitable locations for ocean wave power plants.

<u>OCEAN TIDES:</u>

Ocean tides have potential hydro energy due to the differences in heads between high tide and low tide. Time interval between high tide and low tide is 6hr and 12.5min.

Total potential of the tidal power plant in the world is 2000,000 MW. However present installed capacity is 650 MW.

Types of the ocean tidal power plants are 1) Single pool single effect type ocean tide and 2) single pool double effect ocean tide.

Salient aspects about tidal energy are;

- Over large part of the world tides are of the low crest. Hence energy content is low.
- Very large volumes of water must be used for driving turbine generator of higher unit ratings.
- Due to the low head and low rating, several turbine generator units must be installed to obtain power of the order of 200 MW and above.
- Cost is very high.
- Acceptable technology is available.
- Ocean tidal plants are multipurpose power like water storage, irrigation electricity, fishing etc…

ADVANTAGES AND LIMITAIONS OF OCEAN ENERGY CONVERSION TECHNOLOGIES

Though ocean energy resources are enormous, only a negligible portion is being recovered. Limitations of the ocean energy conversion technologies are:

- Ocean energy resources are with low energy density.
- Large water must be circulated through the energy conversion plant to extract energy. This requires a larger plant with lower power rating.
- Ocean water is corrosive. Special materials, surface coatings are required to prevent corrosion.
- Ocean energy plants require costly civil works.
- Requires costly off shore energy conversion plant and submarine High Voltage Direct Current (HVDC) of electric shore.
- Cost of electricity from ocean energy plant not competitive.

The Merits of the ocean energy conversion technologies are:

- Renewable energy available in very large quantities in many parts of the world.
- Technologies have been developed on pilot scale successfully during 1980s.
- Considering depleting fossil fuel and increasing cost of fossil fuels, ocean energy resources provide a variable alternative.
- Commercial ocean energy conversion plants are being planned and installed under various schemes of non conventional renewable energy which supply useful during coming decades.

The ocean energy technologies are characterized by

- Small and medium plant capacities (60kW to 100 MW).
- Higher capital cost, often prohibited.
- Long distances from on shore to load centers.
- Require favorable topology, geology, ecology.

- Intermittent nature of ocean waves, ocean tides, resulting in low average energy output of the plants.
- Only 1/6 or 1/10 of available energy may be recoverable.
- Costly HVDC technology is required for transmission of power from off shore plant to load center on land.
- High cost of electrical energy, generally non competitive.
-

OCEAN ENERGY ROUTES

Energy routes of ocean energy to useful energy are generally

1. Electrical route is as follows

Ocean Energy → ocean energy converter → electrical energy → transmission distribution

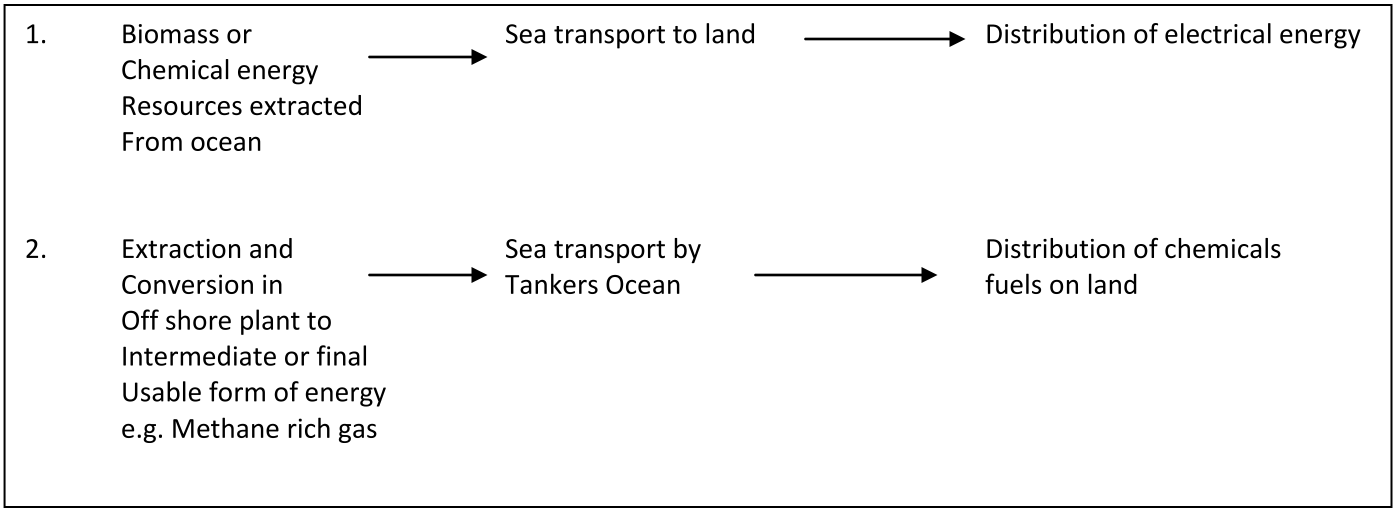
With off shore energy conversion plants the energy transmission from off shore energy conversion plant to land based load canter is in the form of HVDC submarine cable transmission.

AC electrical Energy from Off shore Energy plant → HVDC by AC to DC conversion in off shore Substation → HVDC power transmission by submarine cable → DC to AC inversion in land based substation

With on shore ocean energy, conversion plant, the costly HVDC conversion substations are avoided. The energy route is simpler:

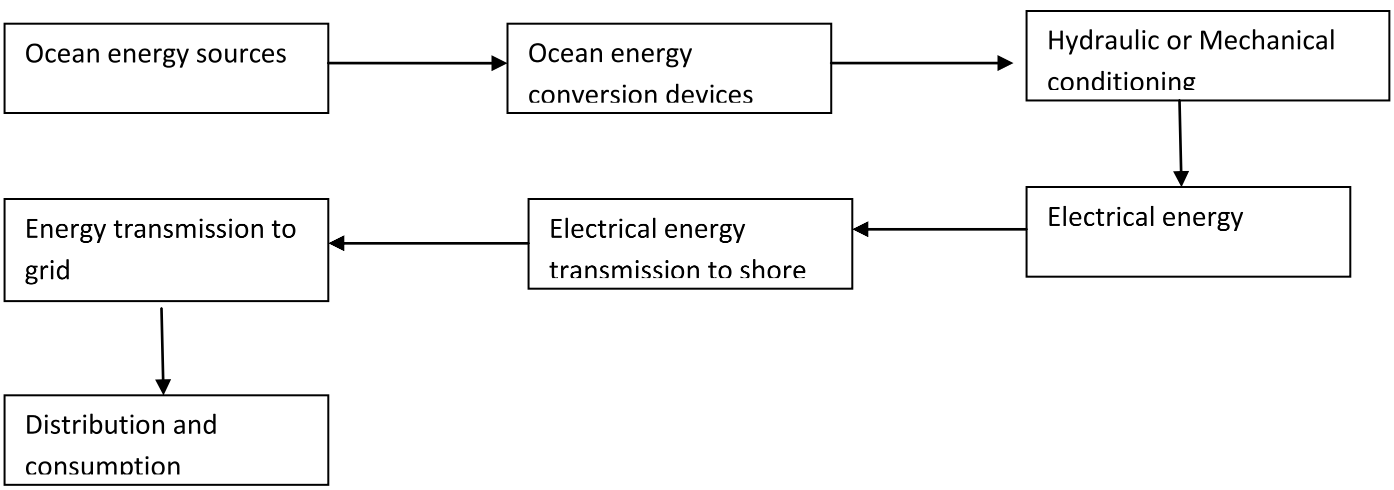
AC electrical Energy from Land based Ocean Energy Conversion plant → AC electrical substation on land → Distribution of electrical energy

2. Ocean biomass routes are as follows



Ocean energy conversion to supply

Electrical route is



Biomass route is