Module 4: WIND ENERGY& TIDAL POWER

Wind energy is another potential source of energy. Winds are the motion of air caused by un- even heating of the earth‘s surface by the sun and rotation of the earth. It generates due to various global phenomena such as ‗air-temperature difference associated with different rates of solar heating. Since the earth‘s surface is made up of land, desert, water, and forest areas, the surface absorbs the sun‘s radiation differently. Locally, the strong winds are created by sharp temperature difference between the land and the sea. Wind resources in India are tremendous. They are mainly located near the sea coasts. Its potential in India is estimated to be of 25×10^3 MW. According to a news release fromAmerican Wind Energy Association the installed wind capacity in India in the year 2000 was 1167 MW and the wind energy production was 2.33×10^6 MWh. This is 0.6% of the total electricityproduction.

Availability of wind energy in India

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world. In 2009- 10 India's growth rate was highest among the other top four countries.
As of 31 Jan 2013 the installed capacity of wind power in India was 19051.5MW, mainly spread across Tamil Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka(2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW) It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power. India's wind atlas isavailable.

Forces on the Blades. There are two types of forces operating on the blades of a propeller-type wind turbine. They are the circumferential forces in the direction of wheel rotation that provide the torque and the axial forces in the direction of the wind stream that provide an axial thrust that must be counteracted by proper mechanical design.

The circumferential force, or torque, T is obtained from

$$T = \frac{P}{\omega}$$

whereT = torque, N or lb,

ω = angular velocity of turbine
wheel, m/s D = diameter of turbine
wheel = $\sqrt{4}$ A/π,m

N = wheel revolutions per unit time, s-1

For a turbine operating at power P, the torque is given by

$$T = \eta \frac{1}{8g_c} \frac{\rho D V_1^3}{N}$$

For a turbine operating at maximum efficiency ηmax = 16/27, the torque is given by Tmax,

$$T_{\max} = \frac{2}{27g_c} \frac{PDV_1^3}{N}$$

The axial force, or axial thrust, is

$$F_a = \frac{1}{2g_c} \rho A(V_1^2 - V_2^2) = \frac{\pi}{8g_c} \rho D^2(V_1^2 - V_2^2)$$

The axial force on a turbine wheel operating at maximum efficiency where V_e = 1/3; $V_i$is given by

$$F_{a,\max} = \frac{4}{9g_c} \rho A V_1^2 = \frac{\pi}{9g_c} \rho D^2 V_1^2$$

The axial forces are proportional to the square of the diameter of the turbine wheel which makes them difficult to cope with in extremely large-diameter machines. There is thus an upper limit of diameter that must be determined by design and economic considerations

The performance of a wind mill rotor stated as coefficient of performance is expressed as:

Cp = A/Pmax
= A/ (1/2 ρV^3)
whereρ = Density of air A
= Swept area
V = Velocity of the wind

Further the tip speed ratio being the function of speed at the tip of the rotor to the windspeed, i.e. U/V and in most of the parts of India, the wind velocity being low (through the wind energy average around 3 kWh/m2 day) The exploitation of wind mills in India is feasible. Depending upon the survey of velocity in a region the appropriate value of design parameter may becomputed

Wind Turbine Classification

Horizontal Axis Machines: Machines with rotors that move in a plane perpendicular to the direction of the wind.

A farmer‘s windmill, for example.

Vertical Axis Machines: Machines that have the working surfaces traveling in the direction of the wind.

Horizontal axis type wind mill

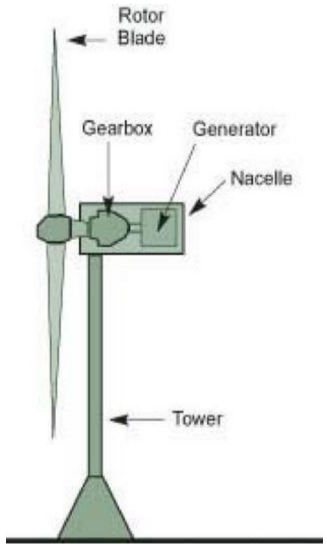


Fig: Horizontal-axis wind turbines

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually positioned upwind of its supporting tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind a small amount. Downwind machines have been built, despite the problem of turbulence (mast wake), because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclical (that is repetitive) turbulence may lead to fatigue failures, most HAWTs are of upwinddesign.

Vertical Axis wind mill

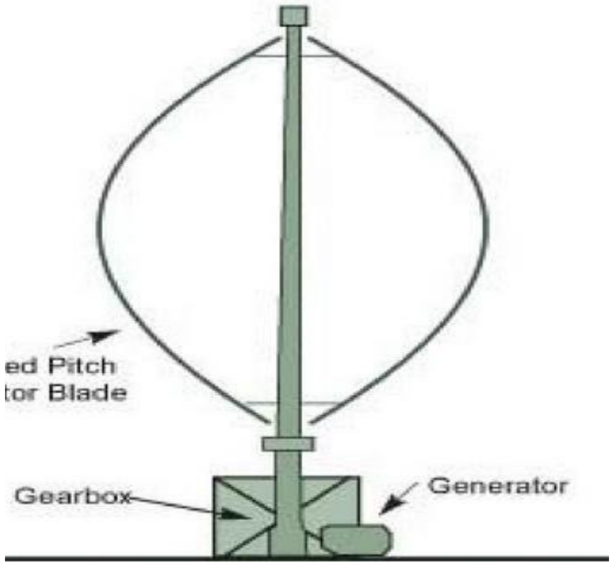


Fig: Vertical-axis wind turbine

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key ad-vantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable, for example when integrated into buildings. The key disadvantages include the low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower powercoefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modelling the wind flow accurately and hence the challenges of analysing and designing the rotor prior to fabricating aprototype

With a vertical axis, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, hence improving accessibility for maintenance.

When a turbine is mounted on a rooftop, the building generally redirects wind over the roof and these can double the wind speed at the turbine. If the height of the roof top mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence.

COEFFICIENT PERFORMANCE OF WIND MILL ROTOR

As WECS is a capital intensive technology it is desirable for the overall wind electric plant to have the highest efficiency possible optimally utilizing capital resources and minimizing the electric energycost

$$\eta = \frac{\text{Useful output power}}{\text{Wind power input}}$$

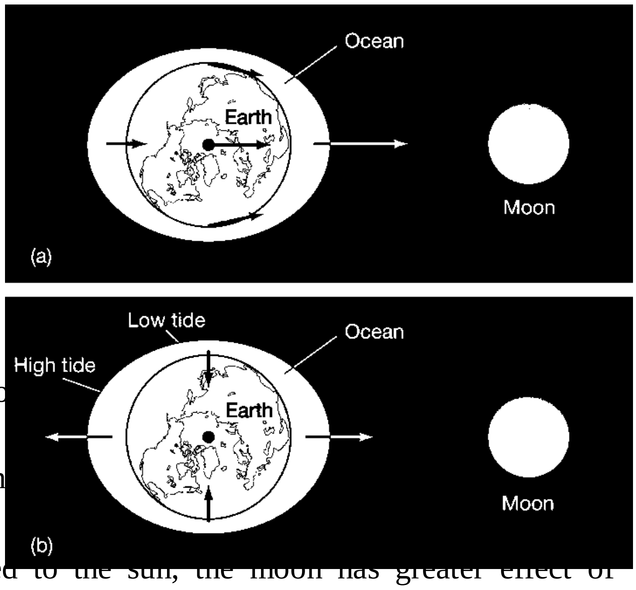
This eqn is an application of cascaded energy conversion, where in overall efficiency will be strongly determined by the lowest efficiency convertor in the cascade. For the aerogenerator this is the aeroturbine; the efficiency of the remaining three elements can be made quite high but less than 100%

TIDAL POWER

TIDAL POWER PLANT

- The periodic rise and fall of the water level of sea which are carried away by the gravitational action of sun and moon is calledtide.
- The energy generated by these tides is called tidalenergy.
- To harness the tidal energy, the difference in water surface elevations at high tide and low tide is utilized to operate a hydraulicturbine.
- A generator is attached to the turbine to generateelectricity.
- The rising water or high tides are called floods and low tides are calledebbs.

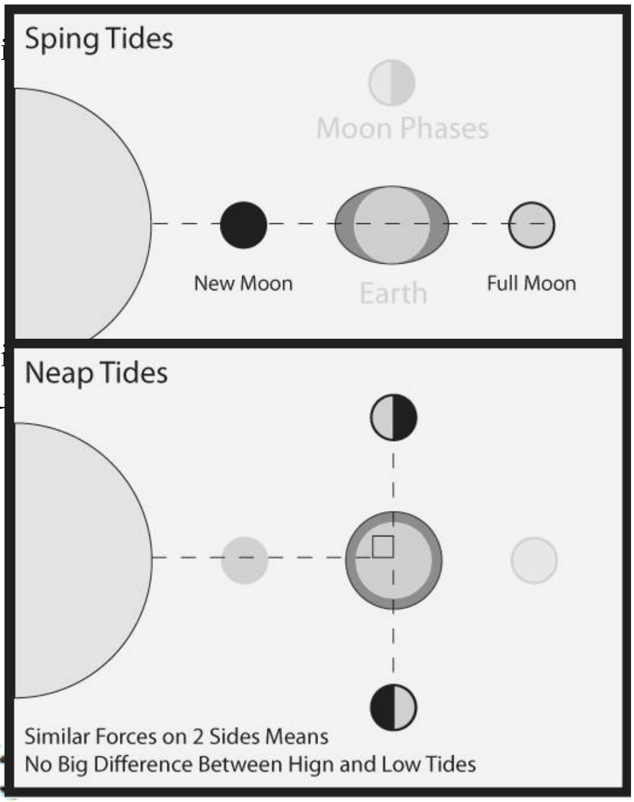
BASIC PRINCIPLE OF TIDAL POWER



- The gravitational attraction of moon and the sun on the water present on the earth produces tides.
- The magnitude of attraction depends on the mass and its distance.
- This is given by Newton's law of gravitation
- It states that "every object in the universe attracts the other object with aforce"
- The gravitational force of attractio proportional to the product of theirmasses.
- The gravitational force of attraction between square of the distance between theircenters.
- Though the moon has less mass compared to the sun, the moon has greater effect of attraction than sun because the distance between the moon and earth is veryless.

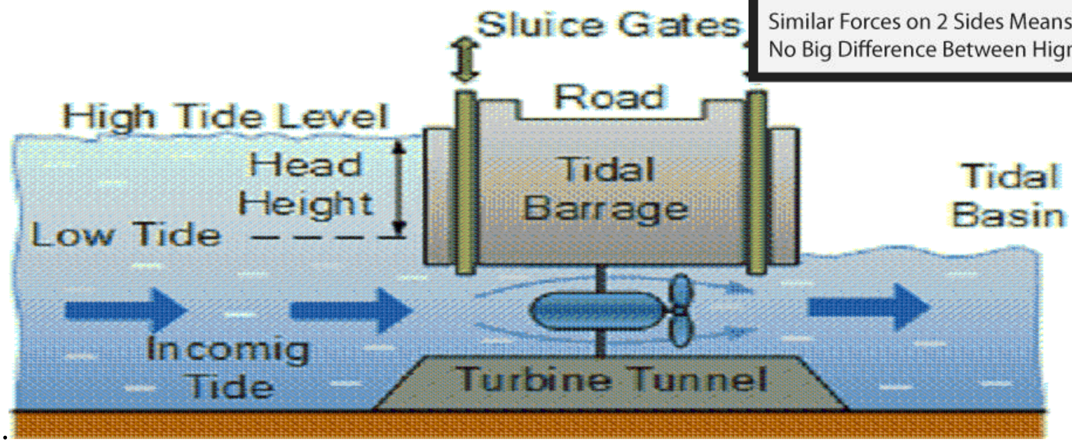
- The gravitational force of the moon causes the oceans to bulge along an axis pointing directly at the moon as shown in thefigure.

When the sun and the moon are in line, their gravitati attraction on the earth combine and cause a spring tide.



When the sun and moon are at 90˚, their gravitati attraction each pulls water in different directions and cau neaptide.

HARNESSING TIDAL ENERGY



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The major components of tidal power plant are:

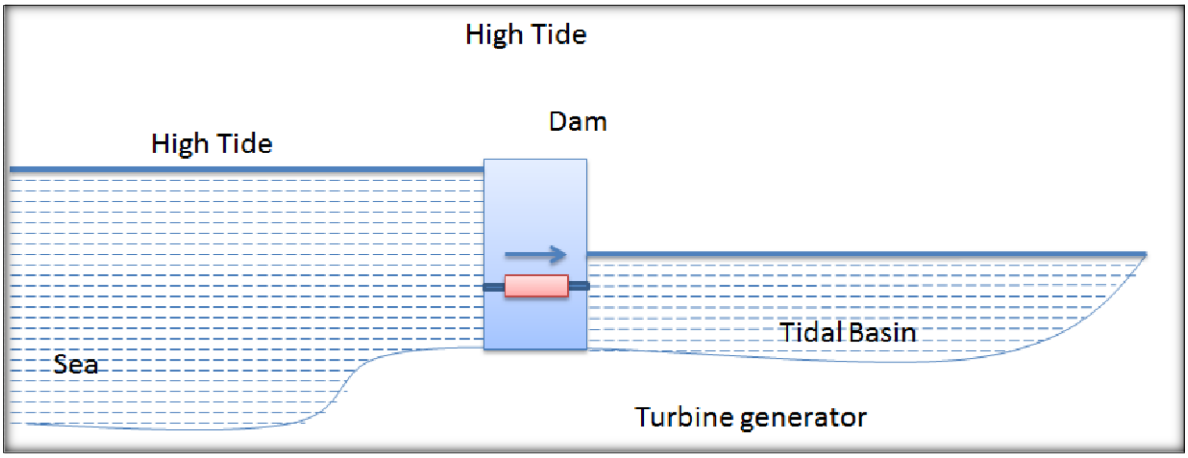
1. Power house- It has turbines, electric generators and other auxiliary equipments.
2. The dam or barrage- The function is to form barrier between sea and basin or between twobasins.
3. Sluice ways- The function is to fill basin during high tides and empty basin during lowtides.

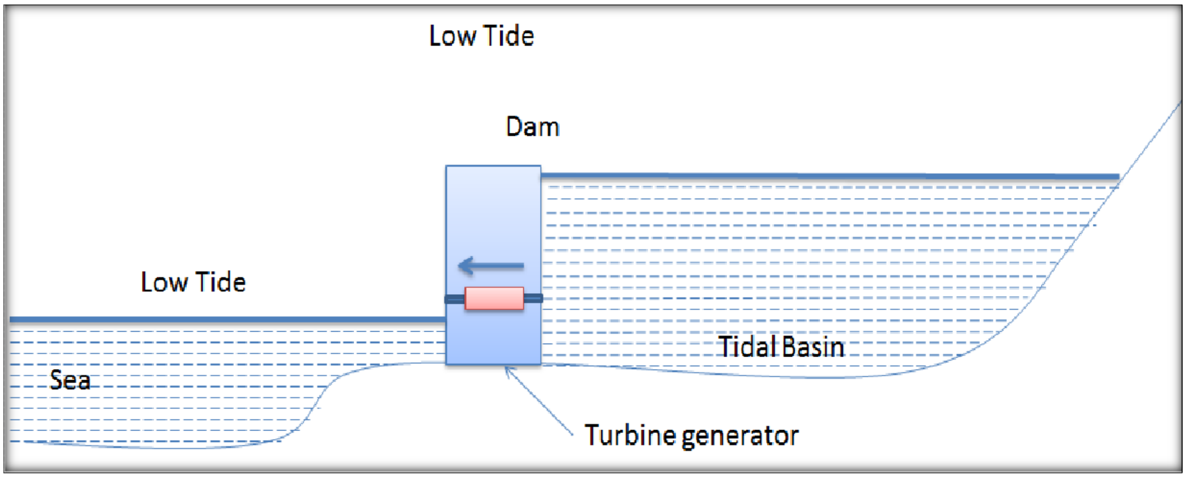
CLASSIFICATION OF TIDAL POWER PLANT

- Single basinarrangement

- Double basinarrangement

SINGLE BASIN ARRANGEMENT





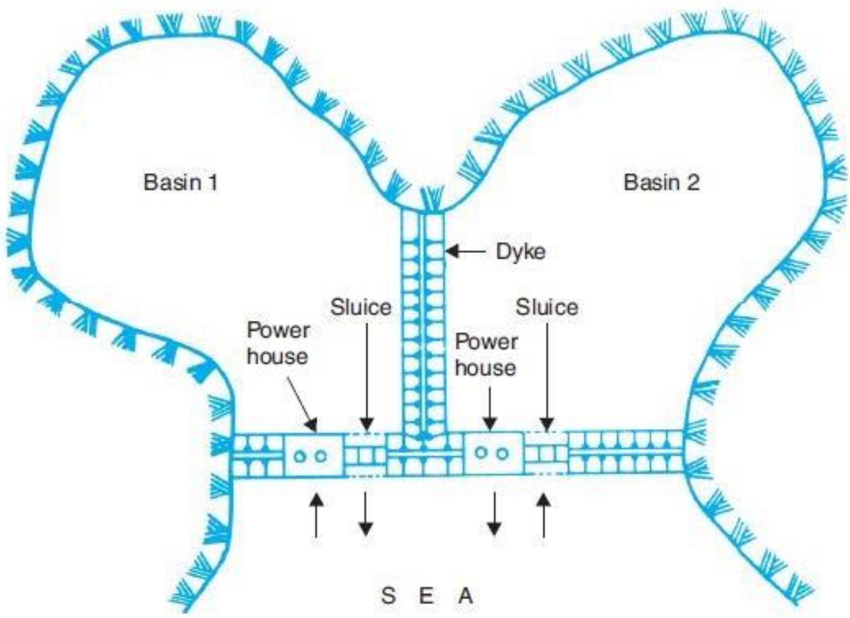
- The general arrangement of a single basin system is shownabove.
- Since only one basin interacts with the sea, power can be generated at regular intervals.
- A dam separates basin and sea. The power house is installed inside thedam.
- During High Tide, i.e., when the sea level rises, the turbine valves are opened and the sea water flows into the basin through the turbine generatingpower.
- The power is generated till the level of sea water and basin isequal.
- The water is allowed to pass into the basin, till the level reaches its maximum position.
- During low tide, the level of basin is more than the level of seawater.
- After attaining sufficient head, the turbine valves are opened and water flows from basin to sea through the turbine generatingpower.
- Tidal power plants normally use reversible water turbines, such that power is generated in both thedirections.

A Single basin arrangement system can be classified as:

1) *Single-ebb system*: Water is stored during High tide in the basin and power is generated only during lowtide.
2) *Single-Tide system*: Power is generated only during High tide and it fills the basin. The water is drained out during lowtide.
3) *Double cycle system*: Power is generated during both high tide and low tide as explainedabove.

DOUBLE BASIN ARRANGEMENT

Two Basin system



- Figure above shows a schematic diagram of two-basinsystem.
- In the system, the two basins close to each other operatealternatively.
- One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied).
- The two basins may have a common power house or may have separate power house for eachbasin.
- In both the cases, the power can be generatedcontinuously.

ADVANTAGES OF TIDAL POWER PLANT

- It is independent of rain, andinexhaustible.
- Large area of valuable land is notrequired.
- When a tidal power plant works in combination with thermal or hydro-electric power plant, peak power demand can be meteffectively.
- Free frompollution.

DISADVANTAGES OF TIDAL POWER PLANT

- Power generation is notuniform.
- Life of turbines reduces due to corrosive seawater.
- Construction of dams in sea isdifficult.
- The power transmission cost is high as it is located away from loadcentres.
- The plant efficiency is notuniform.
- Sedimentation and siltation ofbasins.