5.3 WAVE ENERGY

- Waves get their energy from the solar energy through the wind. Wave energy will never be depleted as long as the sun shines. Energy intensity may, however, have variation but it is available 24 h a day in the entire year.
- They are caused by the wind blowing over the surface of the ocean with enough consistency and force in many areas of the world to provide continuous waves along the shore line. It contains tremendous energy potential and wave power devices extract energy from either the surface motion of ocean waves or from pressure fluctuations below the surface.
- The movement of the ocean water and the changing water wave heights and speed of the swells are the main sources of wave energy. Kinetic energy in the wave motion is tremendous that can be extracted by the wave power devices from either the surface motion of ocean waves or from pressure fluctuations below the ocean surface.

5.3.1 MOTION IN THE SEA WAVES

- ✓ When the wind blows across smooth water surface, air particles from the wind grab the water molecules they touch. Stretching of the water surface by the force or friction between the air and the water creates capillary waves (small wave ripples). Surface tension acts on these ripples to restore the smooth surface, and thereby, waves are formed.
- ✓ The combination of forces due to the gravity, sea surface tension, and wind intensity are the main factors of origin of sea waves as shown in Figure 5.6 , which illustrates the formation of sea waves by a storm. Wave size is determined by wind speed and fetches (defined as the distance over which the wind excites the waves) and by the depth and topography of these abed (which can focus or disperse the energy of the waves). Sea waves have a regular shape at far distance from the fetch and this phenomenon is called swell.
- ✓ Wave formation makes the water surface further rough and the wind continuously grips the roughened water surface, and thus, waves are intensified. A wave is a forward motion of energy and not the water in deep sea. In true sense, the seawater does not move

forward with a wave. Waves are characterized by the following parameters, as shown in Figure 5.3.1

1. Crest: The peak point (the maximum height) on the wave is called the crest.

2. Trough: The valley point (the lowest point) on the wave is called the trough.

3. Wave height (H): Wave height is a vertical distance between the wave crest and the next trough (m).

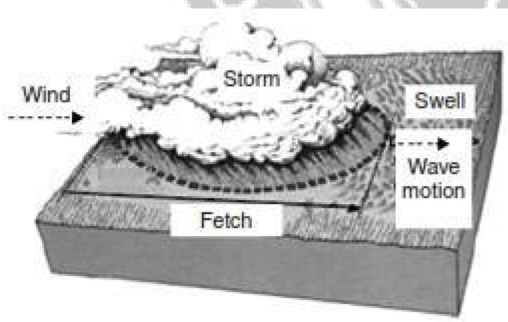
4. Amplitude (a): It is defined as H/2 (m).

5. Wave length ( ): It is the horizontal distance either between the twosuccessive crests or troughs of the ocean waves (m)

6. Wave propagation velocity (v): The motion of seawater in a direction(m/s).

7. Wave period (T): It measures the size of the wave in time(s). It is the timerequired for two successive crests or two successive troughs to pass a point in space.

8. Frequency (f): The number of peaks (or troughs) that pass a fixed point per second is defined as the frequency of wave and is given by f = 1/T (cycle/s).



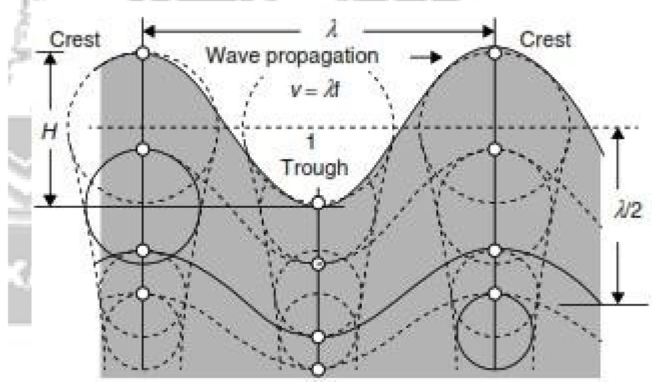


Fig 5.3.1. Sea Wave Formation by Wind Fig 5.5.2. Sea Wave Propagation

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 395]

5.3.2. POWER ASSOCIATED WITH SEA WAVES

- ✓ It has been concluded by researchers through linear wave motion theory that the kinetic and potential energy (E) of a wave per meter of crest and unit of surface can be approximated as

$$E=\rho ga /2$$

Where ρ = density of water; g = gravitational acceleration; and a = amplitude of the wave (Approximately equals to half its wave height H).

- ✓ The power that a meter of crest holds can be obtained by multiplying the amountof energy Transported by the group velocity.

  In deep water, dispersion relation (k) is given ask $=\omega /g$,

  Further, group velocity (Vg) = $\omega /2k = g/2\omega2$
- ✓ The total power (P) is obtained as $P = EVg = [\rho ga\ 2 /2](g/2\ \omega\ ) = \rho g /4\ \omega$

  Further, wave period (T) = $2 / \omega$ or $\omega = 2 /T$ and $a = H/2$

  Therefore, $P =\rho g2\ a\ 2/4\omega = \rho g\ T/32$
- ✓ For irregular waves of height H (m) and period T(s), an equation for power per unit of wave front can be derived as P irregular = 0.4 (kW/m) of wave front From the abovementioned equations, it is seen that the wave power is directly proportional to the square of wave height.

5.3.3 DEVICES FOR HARNESSING WAVE ENERGY

There are three basic technologies for converting wave energy to electricity. They are as follows:

1. Terminator devices: It is a wave energy device oriented perpendicular to the direction of the wave and has one stationary and one moving part. The moving part moves up and down like a car piston in response to ocean waves and pressurizes air or oil to drive a turbine. An oscillating water column (OWC)converter is an example of terminator device. These devices generally have power ratings of 500 kW to 2 MW, depending on the wave parameters and the device dimensions.

2. Attenuator devices: These devices are oriented parallel to the direction of the waves and are long multi-segment floating structures. It has a series of long cylindrical floating devices connected to each other with hinges and anchored to the seabed. They ride the waves like a ship, extracting energy by using restraints at the bow of the device and along its length. The segments are connected to hydraulic pumps or other converters to generate power as the waves move across. Pelamis wave energy converter is one of the known examples of attenuator devices.

3. Point absorber: It is a floating structure with parts moving relative to each other owing to wave action but it has no orientation in any defined way towards the waves instead absorbs the wave energy coming from any direction. It utilizes the rise and fall of the wave height at a single point for energy conversion. The pressurized water creates up and down bobbin type motion and drives a built-in turbine generator system to generate electricity. AquaBuOY WEC is an example of point absorber devices.

4. Overtopping devices: These devices have reservoirs like a dam that are filled by incoming waves, causing a slight build-up of water pressure. Gravity causes released water from reservoir to flow back into the ocean through turbine coupled to an electrical generator. Salter Duck WEC is the example of overtopping devices.

5.3.4 ADVANTAGES AND DISADVANTAGES OF WAVE POWER

Advantages

1. Sea waves have high energy densities and provide a consistent stream of electricity generation capacity.
2. Wave energy is clean source of renewable energy with limited negative environmental impacts.
3. It has no greenhouse gas emissions or water pollutants.
4. Operating cost is low and operating efficiency is optimal.
5. Damage to ocean shoreline is reduced.

5.6.2 Disadvantages

1. High construction costs.
2. Marine life is disrupted and displaced.
3. Damage to the devices from strong storms and corrosion create problems.
4. Wave energy devices could have an effect on marine and recreation environment.