University of Sallahadin
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Distributed Generation

Chapter Nine

Wave Energy

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Definition

- **Wave energy** is the transport of energy by ocean surface waves, and the capture of that energy to do useful work.
- Differential warming of the earth causes pressure differences in the atmosphere, which generate winds
- As winds move across the surface of open bodies of water, they transfer some of their energy to the water and create waves.

Definition

- Wave Energy determined by:
  1. Wave height.
  2. Wave speed.
  3. Wave length.
  4. Water density.
  5. Water depth.

Definition

- The amount of energy transferred and Wave height depends on:

1. The wind speed.
2. The length of time for which the wind blows.
3. The distance over which the wind blows.

Wave Energy

- The energy provided most often used in

1. Electricity generation.
2. Water desalination.
3. Water pumps.

History of Wave Energy

- First concepts 200 years ago.
- Increased interest for renewable energy, and specifically for wave energy, after the energy crisis in 1973, but insufficient money allocated to bring projects to maturity.
- 80’ because of oil price fall, wave energy funding reduced significantly.
- 90’ growing awareness of the potential of generating energy from waves.

Wave Energy Harness

- In order to extract wave energy, wave energy conversion devices must create a system of reacting forces, in which two or more bodies move relative to each other, while at least one body interacts with the waves.

Wave Energy Harness

- Waves retain energy differently depending on water depth.
  - Lose energy **slowly** in **deep water**.
  - Lose energy **quickly** as water becomes **shallower** because of friction between the moving water particles and the sea bed.
- Wave energy conversion devices are designed for optimal operation at a particular depth range.

Wave Energy Devices Classification

- Wave energy devices can be classifies in terms of their location:

1. **Shoreline**: Tied with cables in intermediate depths.
2. **Near shore**: Fixed to the seabed in shallow water.
3. **Offshore**: more difficult to construct and maintain than shoreline but greatest potential as waves in deep water have greater energy content.

On-shore versus Off-shore

On-shore technologies Advantages

1. Easier to access for construction and maintenance.
2. Less installment costs and grid connection charges.
3. Could be incorporated into harbor walls or water breaks, performing a dual service for the community.

On-shore versus Off-shore

On-shore technologies Disadvantages

1. Limited number of suitable sites.
2. Environmental concerns for on-shore devices are greater.
3. Much less energy available to on-shore devices because water depth usually decreases closer to the shore.

Wave Energy Technologies

Technologies used to harness the wave energy:

1. Point absorber
2. Surface attenuator
3. Oscillating wave surge converter
4. Oscillating water column
5. Overtopping device
6. Submerged pressure differential

Wave Energy Technologies

Point absorber buoy

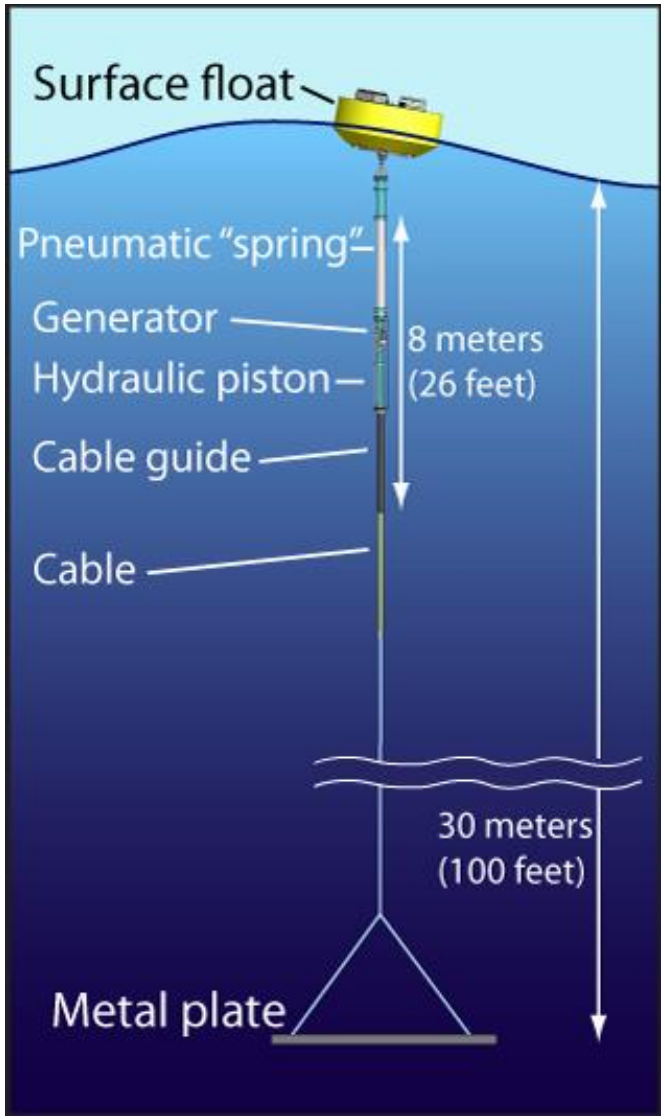
- This device floats on the surface of the water, held in place by cables connected to the seabed.
- Buoys use the rise and fall of wavers to drive hydraulic pumps and generate electricity. Electromagnetic field generated by electrical transmission cables and acoustic of these devices may be a concern for marine organisms.

Wave Energy Technologies

Point absorber buoy

Environmental effects:

- It affect fish, marine mammals, and birds lives.
- Energy removed from the waves also affect the shoreline.



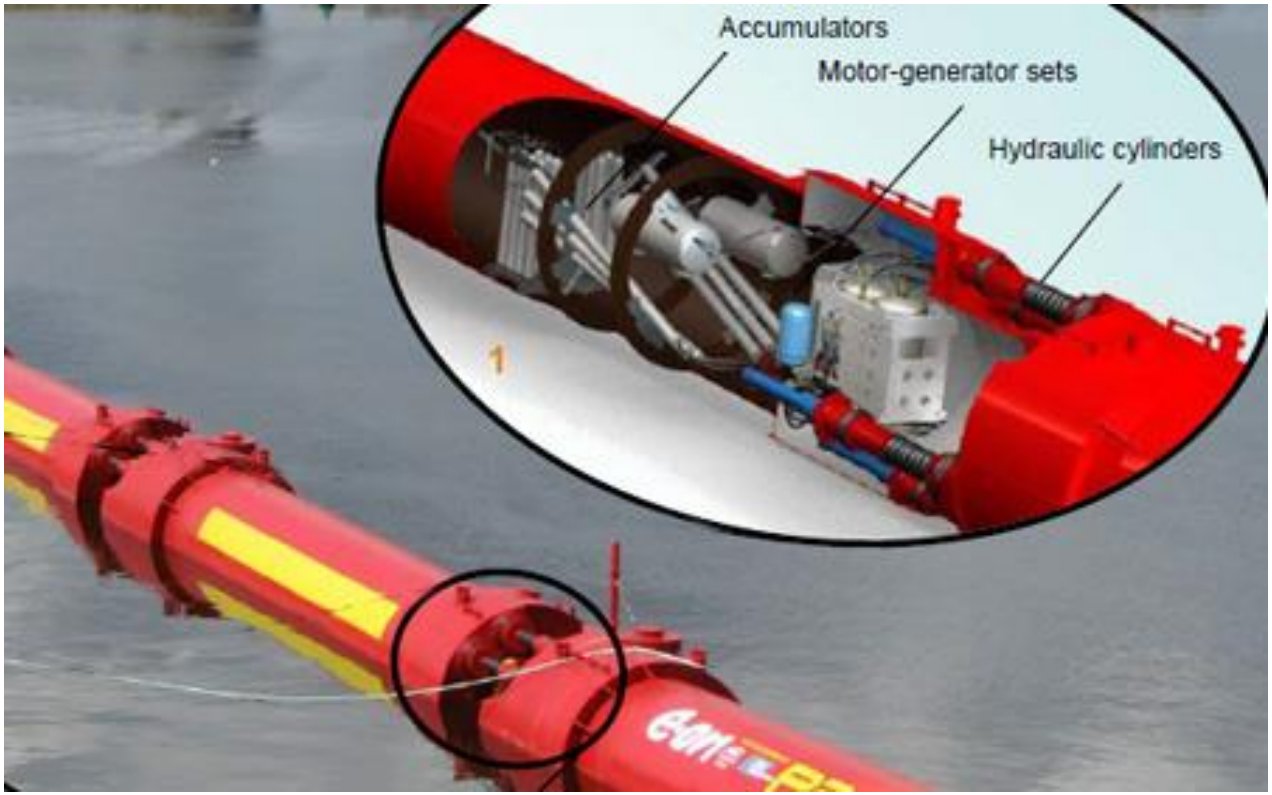
Wave Energy Technologies

Surface attenuator

- These devices act similarly to point absorber buoys, with multiple floating segments connected to one another and are oriented perpendicular to incoming waves.
- A flexing motion is created by waves that drive hydraulic pumps to generate electricity.

Wave Energy Technologies

Surface attenuator



- **Environmental effects** are similar to point absorber, with an additional concern that organisms could be pinched in the joints.

Wave Energy Technologies

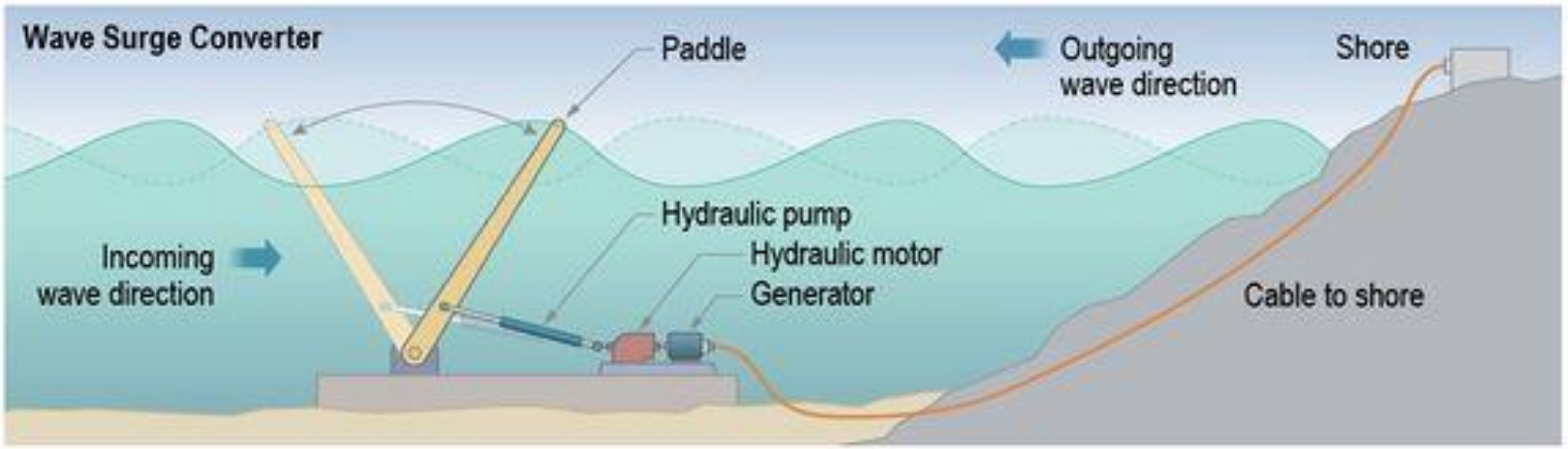
Oscillating wave surge converter

- These devices typically have one end fixed to a structure or the seabed while the other end is free to move.

Wave Energy Technologies

Oscillating wave surge converter

- Energy is collected from the relative motion of the body compared to the fixed point.
- Oscillating wave surge converters often come in the form of floats, flaps, or membranes.



Wave Energy Technologies

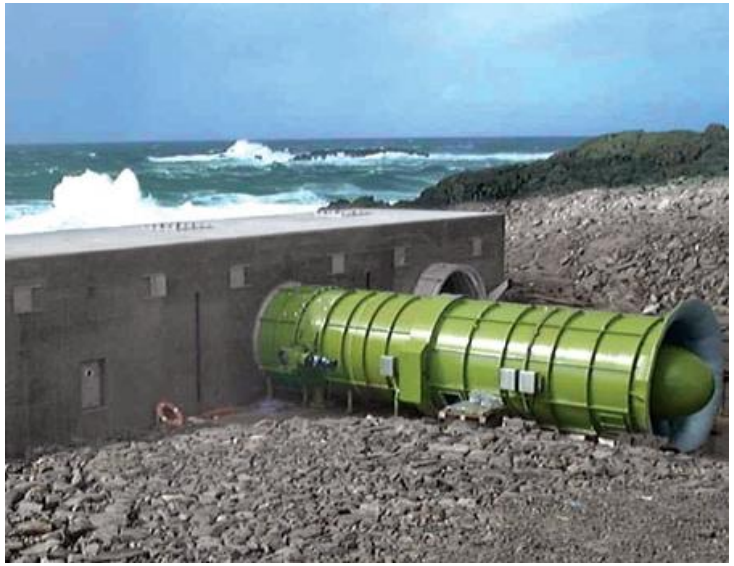
Oscillating wave surge converter

- Some of these designs incorporate parabolic reflectors as a means of increasing the wave energy at the point of capture.
- These capture systems use the rise and fall motion of waves to capture energy.
- Once the wave energy is captured at a wave source, power must be carried to the point of use or to a connection to the electrical grid by transmission power cables.

Wave Energy Technologies

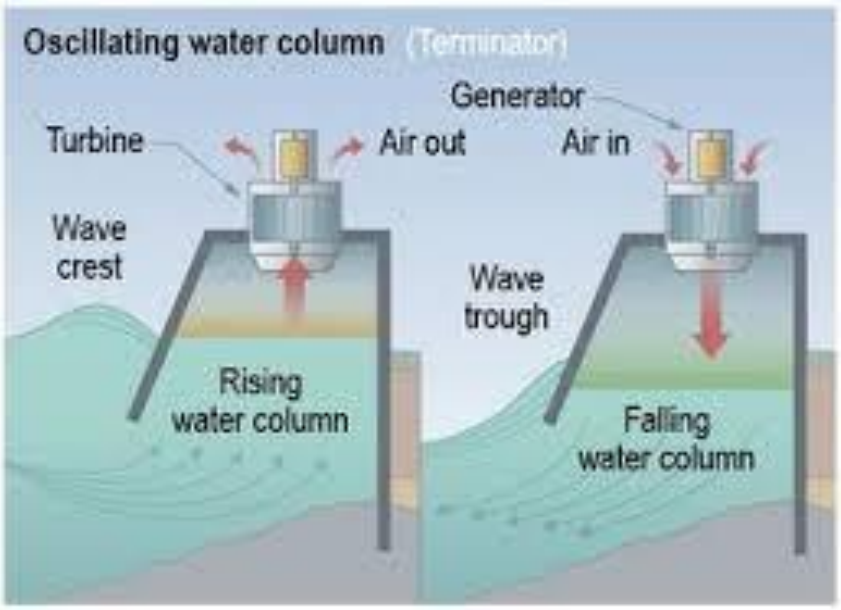
Oscillating water column

- Oscillating water column devices can be located on shore or in deeper waters offshore.
- With an air chamber integrated into the device, swells compress air in the chambers forcing air through an air turbine to create electricity.

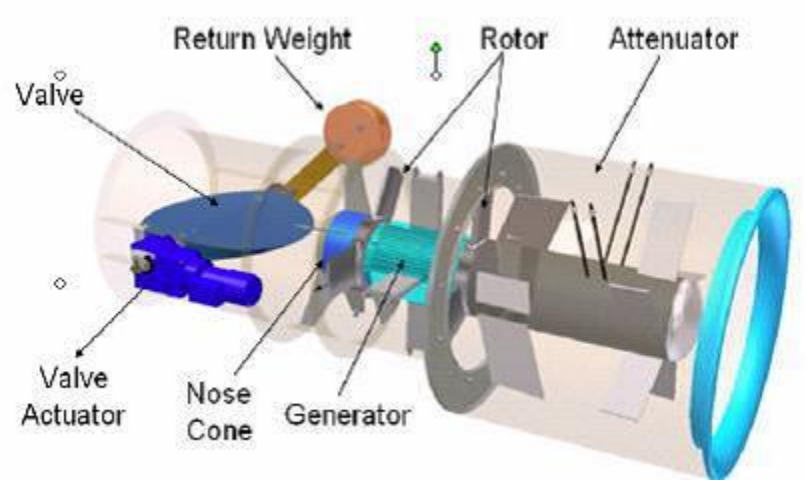


Wave Energy Technologies

Oscillating water column



Oscillating water column working method



Oscillating water column parts diagram

Wave Energy Technologies

Oscillating water column

- *As a wave enters the collector, the surface of the water column rises and compresses the volume of air above it.*
- *The compressed air is forced into an aperture at the top of the chamber, moving past a turbine.*
- *As the wave retreats, the air is drawn back through the turbine due to the reduced pressure in the chamber.*
- *The turning of the turbine drives a generator, producing electricity.*

Wave Energy Technologies

Oscillating water column

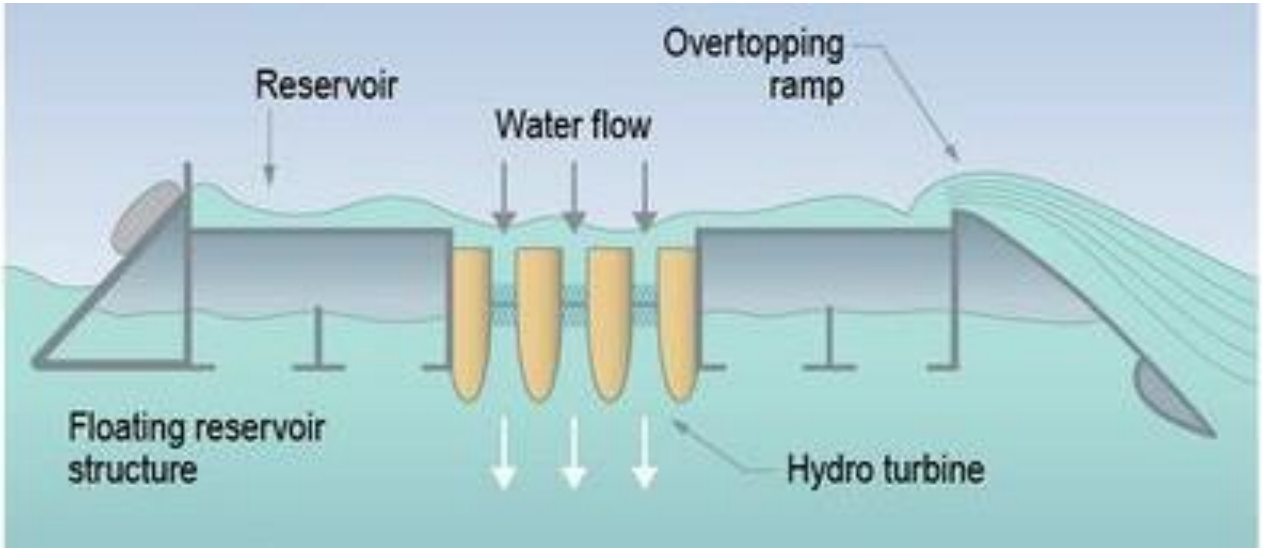
Environmental effects:

- Significant noise is produced as air is pushed through the turbines, potentially affecting birds and other marine organisms within the vicinity of the device.
- There is also concern about marine organisms getting trapped or entangled within the air chambers.

Wave Energy Technologies

Overtopping device

- Uses wave velocity to fill a long structure reservoir to a greater water level than the surrounding ocean.
- The potential energy in the reservoir height is then captured with low-head turbines.



Wave Energy Technologies

Overtopping device

- Devices can be either on shore or floating offshore.
- Floating devices will have environmental concerns about the mooring system affecting benthic organisms, organisms becoming entangled, or EMF effects produced from subsea cables.
- There is also some concern regarding low levels of turbine noise and wave energy removal affecting the near field habitat.

Wave Energy Advantages

1. Low noise
2. Low visual impact
3. No impact for fish like tidal energy
4. Wave power provides the highest kW intensity per m^2
5. Wave available 4000 hours per year (more than wind)

Wave Energy Disadvantages

1. Most turbines require a constant, powerful flow because waves are irregular in both direction and power.
2. Storms damages and corrosive power of saltwater.
3. Devices still complicated at mechanic level and engineering difficulties.
4. Maintenance of devices expensive.
5. Problem of lose during conversion from mechanical energy to electricity.

Wave Energy Calculations

The per meter wave power:

$$P_w = \frac{\rho\, g^2\, h^2\, T}{16\pi}$$

ρ is the density of water kg per cubic meters.

g is Earth's gravity = 9.81 meters per second squared.

h is the wave height in meter.

T is wave period in seconds.

Wave Energy Calculations

The net wave power per length:

$$P = \eta \times l \times P_w$$

Annual output power:

$$E = P \times 24 \text{ hours} \times 365 \text{ days}$$

η is the conversion efficiency.

l is wave inlet for a wave energy system in meters.

Wave Energy Calculations

Example:

For a wave height of 3m and wave period of 8s, if a wave inlet for a wave energy system is 50m ,conversion efficiency is 0.8 and water density is 1025kg/m^3, calculate:

1. The wave power.
2. The net wave power per length.
3. Annual power output.

References

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Next Lecture

- Geothermal

Questions and Thank you