Ocean Energy Glossary

Prepared by the Wave Energy Centre with support of the Co-ordinated Action of Ocean Energy EU funded Project (CA-OE) within a collaborative action with the Implementing Agreement on Ocean Energy Systems (IEA-OES)

WaveEnergy Centre

Sixth Framework Programme

IEA | OES Ocean Energy Systems

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INTRODUCTION

1. Background

The Ocean Energy Glossary was prepared under the **Co-ordinated Action on Ocean Energy (CA-OE)**, a 3-years project (2005 -2007) established and supported by funding from European Commission Sixth Framework Research Programme for Energy Environment and Sustainable Development.

The initiative of developing an Ocean Energy Glossary was seconded by the **International Energy Agency's Implementing Agreement on Ocean Energy Systems (IEA OES)** as one of its collaborative actions with the CA-OE project.

*'The main objective of the **Coordinated Action on Ocean Energy** is to develop a common knowledge base necessary for coherent development of R&D Policies in Europe, the dissemination of this knowledge base and promotion of ocean energy technologies'*

*'The **IEA-OES** was established in 2001 with the mission to facilitate and co-ordinate ocean energy research, development and demonstration through international co-operation and information exchange, leading to the deployment and commercialisation of sustainable, efficient, reliable, cost-competitive and environmentally sound ocean energy technologies'*

While the initial elaboration of the glossary and the interpolation towards the first published version of this glossary is done within CA-OE that terminates by October 2007, the updating will be done under IEA-OES.

2. Aim of the Ocean Energy Glossary

The primary aim of this glossary is to provide an efficient and fast reference to the ocean energy specific terms for professionals and the general public. Further, it is meant to give some contribution to promoting best practice and use of common concepts in the ocean energy field. Given the role of international organisations in promoting the use of "standard" concepts, the IEA-OES proposed in collaboration with the CA-OE project to develop a glossary to influence harmonization of terminology in Ocean Energy.

3. Description of the Ocean Energy Glossary

The Ocean Energy Glossary contains a comprehensive set of definitions of the main terms in the field of wave energy, marine current energy (tidal stream), tidal energy, OTEC and Salinity Gradient.

The definitions in the Ocean Energy Glossary are primarily based on the comprehensive **Marine Energy Glossary** that was developed by Entec UK Ltd in partnership with the Carbon Trust (2005)[1].

The Glossary will be continually evolving and suggestions for additional terms or comments on existing terms are welcome. This Glossary will be available on the IEA-OES website and the update of the contents will be an on-going activity of the IEA-OES.

[1] http://www.carbontrust.co.uk/technology/technologyaccelerator/glossary.htm

3.1 Links to other glossaries on the Internet

A number of other international organisations have compiled glossaries that provide definitions of some key concepts used as well in ocean energy. Links to some of these glossaries are provided below:

- **The Encyclopedia of Alternative Energy and Sustainable Living**
  The Encyclopedia is a large, free, on-line resource aimed at providing accurate information on living in harmony with our planet, particularly with regard to green energy and architecture.

  http://www.daviddarling.info/encyclopedia/T/AE_tidal_barrage.html

- **Tide and Current Glossary**
  Center for Operational Oceanographic Products and Services (CO-OPS), which manages a portal to the National Oceanic and Atmospheric Administration's collection of oceanographic and meteorological data

  http://tidesandcurrents.noaa.gov/publications/glossary2.pdf

- **Glossary of Coastal Engineering Terms**
  Coastal Data Information Program (CDIP) - extensive network for monitoring waves along the coastlines of the United States.

  http://cdip.ucsd.edu/?nav=documents&sub=faq&xitem=glossary

3.2 Links to other useful related references

A clear explanation of ocean energy principles can be found in the following links:

- **Overview of ocean energy**

  - European Commission

  http://www.europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_oes/article_1128_en.htm

  - João Cruz (editor): "Ocean Wave Energy: Current Status and Future Perspectives" (Springer, 2007)

- **Marine Current Energy (or tidal stream energy)**

  ESRU - Energy Systems Research Unit (Marine Current Resource and Technology Methodology)

  http://www.esru.strath.ac.uk/EandE/Web_sites/05-06/marine_renewables/home/welcome.htm

- **Tidal energy**

  Report from the *Sustainable Development Commission*, 2007 "Turning the Tide: Tidal Power in the UK" available at http://www.sd-commission.org.uk/

- **Salinity Gradient**

  Statkraft, 2006, "Osmotic Power: A huge renewable energy source"

  http://www.statkraft.de/pub/innovation/teknologiutvikling_i_statkraft/saltkraft/hva_er_osmose.asp

- **Ocean Thermal Energy Conversion (OTEC)**

  NREL - National Renewable Energy Laboratory

  http://www.nrel.gov/otec

A

accumulator
A device for storing energy for long or short periods and which can release the stored energy in the same form as it was supplied.

absorbed [wave] power
The power which an oscillating system removes from the waves.

absorption width
The same as **capture width**. A measure for a wave-power device's ability to capture power from a wave. The ratio between absorbed power and the wave power level.

added mass
The hydrodynamic forces due to waves on an immersed object can be expressed in terms of two complex components: one in phase with the acceleration and one in phase with the velocity of the device. The force in phase with the acceleration can be expressed in terms of an extra point mass fixed to the device - this is known as the **added mass**. The force in phase with the velocity of the device can be expressed in terms of a velocity force as an applied damping - this is known as the **hydrodynamic damping**.

amplitude
The maximum extent or magnitude of a vibration or other oscillating phenomenon, measured from the equilibrium position or average value.

angular frequency
Angular frequency ω (also referred to by the terms angular speed, radial frequency, and radian frequency) is a scalar measure of rotation rate. Angular frequency is the magnitude of the vector quantity angular velocity.

array
An arrangement of similar devices. In ocean energy devices this means a number of similar devices arranged into a single group to provide a combined energy output. Also known as a "farm".

asynchronous generator
Same as **induction generator**. A type of electric **generator** that produces alternating current that matches an existing power source, therefore adequate for use in RE applications. Below synchronism the machine acts as an induction motor (consuming electrical energy), at synchronism the machine acts as generator (driven by mechanical power).

attenuator
A device which is aligned along with the predominant direction of wave incidence.

availability
The degree to which a system is free from degradation or interruption in its output resulting from component failures, maintenance or operational scheduling. Availability is often expressed as a annual percentage derived from the following equation: Availability= Time available for operation / Total time in period.
The time available for operation is regardless of whether the prevailing conditions are suitable for energy production. So it includes all times when the machine is turned off during storms for example, but when no fault is present.

Availability Reliability Maintainability (ARM)
A formal analysis process conducted to determine the likely availability, reliability and maintainability of a system. This process recognises the connections between all these aspects. This allows a traceable analysis that can be used to predict the life costs of any system.

axial flow water turbine
The Axial flow turbines are used for Low head and relatively high flow rates in hydro electric plants. Consequently they are suitable for tidal energy barrages or wave energy converters using overtopping. There are many types of axial flow turbines as Tubular, Rim, Bulb etc. The type depends to the arrangement of the electrical generator. The axial flow water turbines could be equipped with adjustable runner blades.

B

bandwidth
A bandwidth describes the range of wave frequencies over which a wave energy device responds.

bathymetry
The measurement of water depth and the shape of seabed - often as shown on a map of the sea or hydrographical chart.

bulb turbine
It is a type of **axial flow turbine**. A type of turbines for use in a **tidal barrage**. The bulb turbine is derived from Kaplan turbines with the generator contained in a waterproofed bulb submerged in the flow. The La Rance tidal plant near St Malo on the Brittany coast in France uses bulb turbines.

buoys
An anchored floating device. Traditionally these have served as navigation marks or for mooring but now can be incorporated to wave energy devices. They are typically small compared to the incoming wavelengths, thus are a common form of point absorber.

C

capacity factor
Same as **load factor** or **full load factor**. The ratio of the mean generation to the peak generation on a renewable energy generator. Either expressed in percentage (referring to a reference time period) or in equivalent full load hours per year.

capture width
The same as **absorption width**. A measure for a wave-power device's ability to capture power from a wave. The ratio between absorbed power and the wave power level.

closed-cycle OTEC System
Two basic OTEC system designs have been demonstrated to generate electricity: **closed cycle** and **open cycle**. In the closed-cycle OTEC system, warm seawater vaporizes a working fluid, such as ammonia, flowing through a heat exchanger (evaporator). The vapour expands at moderate

pressures and turns a turbine coupled to a generator that produces electricity. The vapour is then condensed in another heat exchanger (condenser) using cold seawater pumped from the ocean's depths through a cold-water pipe. The condensed working fluid is pumped back to the evaporator to repeat the cycle. The working fluid remains in a closed system and circulates continuously.

conversion efficiency
The conversion efficiency (η) of a device is the proportion of energy converted to a useful form (e.g. Electricity) compared to the total energy available to the device.

coriolis
An effect whereby a mass moving in a rotating system experiences a force perpendicular to the direction of motion and to the axis of rotation.

counrerrotating turbine
Air turbine consisting of two **Wells Turbines** placed close together with their blades rotating in opposite directions. Each behaves like a set of guide vanes for the other.

D

damping
A mechanism for bringing about a reduction in the amplitude of a vibration or oscillating by extracting energy. In a power plant the damping is the part of the load that acts in phase with the velocity. Damping is usually expressed as the force per unit velocity [N/(m/s)].

damping coefficient
See **hydrodynamic damping.**

Darrieus turbine
A cross-axis turbine type common in early wind turbine designs, which may have application in tidal stream energy, and possibly in wave energy. The Darrieus turbine has long, thin blades in the shape of loops connected to the top and bottom of the axle.

deep water
Water sufficiently deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wave length is considered deepwater.

deep water waves
A wave in water the depth of which is greater than one-half the wavelength.

direct drive
When the power take off system is designed to convert the mechanical energy of a drive shaft into the desired energy form, without any intermediate conversions. Usually used for power conversion systems where the gearbox or hydraulics is excluded by specially designed electric generators but should also be applicable for systems where water is pumped by a mechanical water pump, directly connected to the drive shaft of a wind turbine, instead of converting the power into electricity and use an electrical water pump.

diffraction problem
A body, which is at least partly immersed in water, and which is able to perform oscillations, may interact with waves in various ways: In an incident wave the body may experience an oscillating force even if it is immobilised – this is known the diffraction problem or **scattering problem**. See also radiation problem.

directional wave spectrum
A two-dimensional spectrum that shows how the wave energy is distributed between various directions of incidence, in addition to how it is distributed among various frequencies.

displacer
The part of a wave energy device that moves in response to the waves. Power is usually taken of from the relative motions of the reactor and displacer.

distribution system
An electric grid network that is used to distribute power to a number of loads. The system can be composed of cables operating at several set voltages.

drag
The retarding force exerted on a body moving relative to a fluid. Drag is usually an energy loss process. It can arise in water movements as friction on wetted surfaces or as vortex shedding from fluid flowing past solid object corners.

duct
With particular application to tidal stream turbines; a duct is a cowling placed around a turbine to enhance the flow through the rotor. The term duct can also apply to the part of oscillating water columns where the air turbine is placed.

E

eigenfrequency
See **natural frequency**.

end-stop (-device, -mechanism)
In some wave energy devices it is sometimes necessary to include a deceleration cushion at the end of the stroke, using a end-stop device that dissipates kinetic energy of the load gently, and reduces the possibility of mechanical damage to the device.

energy frequency (fe)
The frequency corresponding to the **energy period** (Te), fe=1/Te [Hz].

energy period (Te)
Real sea waves can be described as a series of superimposed waves of different periods and amplitudes. The energy period is the period of a monochromatic (single frequency) wave containing the same energy as the real sea state.

environmental impact assessment (EIA)
The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made. Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made.

exciting force
The force which an incident wave exerts on a body, when it is not moving.

excursion
The distance moved by a body relative to the instantaneous water surface level.

F

far field
In a wave field a boundary distant from a certain point can be defined. The energy passing through this boundary must be in equilibrium. This boundary is known as the far field.

farm
See **park**.

fast tuning
Fast tuning requires changing characteristics of a device to adjust (or ideally to maximise) the energy capture. Fast tuning means adjustments for each wave or loosely over a period of around 1 second for real-sea waves. Also known as wave-by-wave tuning.

Field trials
See **sea trials**.

flywheel
Frequently mentioned short-term energy storage mechanism. Flywheels provide energy storage in the form of rotational kinetic energy. Other types of storage are: pressure accumulators and water reservoirs.

free surface
In marine energy this typically means the surface of the water.

frequency
In particular application to wave energy the frequency is the water/sea wave frequency. It is measured in Hertz [Hz] or [radians/s].

frequency domain
When analysing periodic information it is sometimes beneficial to consider using the frequency domain. Such analyses transform the problem into one of frequency components.

frequency response
An oscillating system such as a resonant wave energy device can be excited by a varying force such as that from interactions with waves. The degree to which the system is affected by the force is its response. The frequency response of a system is particularly the extent to which that system is affected by particular frequencies of forcing. The relationship between the device's response and the frequency of the incoming waves is its frequency response.

Full load factor
Same as **load factor** and **capacity factor**.

G

generator
A device that converts mechanical power at the generator shaft to electrical power.
They may be driven by air turbines, water turbines, etc. Generators are rated by watts (W)

grid
A network of interconnected cables for transmitting and/or distributing electricity.

guide vanes
Guide vanes are used to enhance the performance of the **Wells turbine**.

H

hydrodynamic coefficients
See **added mass** and **hydrodynamic damping.**

hydrodynamic damping
The hydrodynamic forces due to waves on an immersed object can be expressed in terms of two complex components: one in phase with the acceleration and one in phase with the velocity of the device. The force in phase with the acceleration can be expressed in terms of an extra point mass fixed to the device - this is known as the **added mass**. The force in phase with the velocity of the device can be expressed in terms of a velocity force as an applied damping - this is known as the **hydrodynamic damping**.

harmonic
A harmonic is a single frequency that is an exact integer multiple of the fundamental or natural frequency of system.

heave
Linear oscillatory motion (translation) of an immersed body or structure in the vertical direction.

hybrid OTEC System
A hybrid cycle combines the features of both the **closed-cycle** and **open-cycle** systems. In a hybrid OTEC system, warm seawater enters a vacuum chamber where it is flash-evaporated into steam, which is similar to the open-cycle evaporation process. The steam vaporizes the working fluid of a closed-cycle loop on the other side of an ammonia vaporizer. The vaporized fluid then drives a turbine that produces electricity. The steam condenses within the heat exchanger and provides desalinated water.

horizontal axis turbine
A **tidal stream turbine** mounted such that it rotates about a horizontal axis, typically running parallel with the flow direction.

I

impulse turbine
Most popular alternative to the Wells turbine for use in OWC plants. Its rotor is basically identical to the rotor of a conventional single-stage steam turbine of axial-flow impulse type. Since the turbine is required to be self-rectifying, instead of a single row of guide vanes there are two rows, placed symmetrically on both sides of the rotor. These two rows of guide vanes are like the mirror image of each other with respect to a plane through the rotor disc.

Induction generator
Same as **asynchronous generator**.

installed capacity
The installed capacity of a device is the total power that the device can produce when operating correctly and at full power output. Traditionally this is the installed capacity of the electrical generator in a device. Installed capacity is usually measured in kilowatts [kW] or megawatts [MW].

J

joint probability
See **scatter diagram**.

K

kilowatt (kW)
A standard unit of electrical power equal to 1000 watts.

kilowatt-hour (kWh)
A unit or measure of electricity supply or consumption of one thousand watts acting over a period of one hour. The kWh is a unit of energy. 1 kWh = 3600 kJ

L

latching
Latching is a method of control. The aim is to deliberately hold back or "latch" a device the term linear means that all oscillating variables are sinusoidal and proportional (in the case of waves) to wave height. Linear often implies relatively small motions or amplitudes.

linear generator
The main difference of a linear generator to a conventional generator is that the motion of the rotor is linear.

linear theory
Linear theory in wave energy often implies relatively small motions or amplitudes.

load factor
Same as **full load factor** and **capacity factor**.

M

marine current
See **tidal stream**. Can also relate to a flow of water induced by temperature gradients i.e. the Atlantic conveyor.

mean spectral period
See **zero crossing period.**

mean wave power
Mean power is the average power in a real (polychromatic) sea. It is usually measured in kilowatts or megawatts.

megawatt (MW)
1 megawatt = 1 million **watts.**

monochromatic wave
Wave with the same length and period.

N

n-th order moment of wave spectrum
A power (n) of the frequency multiplied by the wave-energy spectrum and integrated over all frequencies.

natural frequency
The frequency of vibration of an oscillating system when vibrating freely.

near field
The region near to a point where calculation of energy flux can be complex and difficult to determine. The near field contrasts with the far field, which is much simpler to describe mathematically.

nearshore
(1) In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker or surf zone. (2) The zone which extends from the SWASH zone to the position marking the start of the offshore zone, typically at water depths of the order of 20 m.

O

O&M
See **Operation & Maintenance.**

ocean energy
Ocean energy covers a series of emerging technologies that use the power of **waves**, ocean **currents**, **tides**, **ocean thermal energy gradient** and **salinity gradient** to generate energy.

Ocean thermal energy conversion
Ocean thermal energy conversion or OTEC, is an energy technology that converts solar radiation to electric power. OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power.

Open-cycle OTEC system
Two basic OTEC system designs have been demonstrated to generate electricity: **closed cycle** and **open cycle**. In an open-cycle OTEC system, warm seawater is the working fluid. The warm seawater is "flash"-evaporated in a vacuum chamber to produce steam at an absolute pressure of about 2.4 kilopascals (kPa). The steam expands through a low-pressure turbine that is coupled to a generator to produce electricity. The steam exiting the turbine is condensed by cold seawater pumped from the ocean's depths through a cold-water pipe. If a surface condenser is used in the system, the condensed steam remains separated from the cold seawater and provides a supply of desalinated water.

Operation & Maintenance (O&M)
A term used to describe the combined activities for operating and maintaining a system. Also refers to the manuals supplied by the technology supplier to the

system operator to provide all the necessary information on the proper, efficient and safe operation of a system or device.

osmosis
Net movement of water across a **selectively permeable membrane** driven by a difference in **osmotic pressure** across the membrane. A selectively permeable membrane allows passage of water, but rejects solute molecules or ions. When freshwater and saltwater is separated by a proper membrane the freshwater will spontaneously migrate through the membrane and dilute the saltwater (the process known as osmosis).

osmotic pressure
Pressure which, if applied to the more concentrated solution, would prevent transport of water across a **semipermeable membrane.**

osmotic pressure diference
Between two bodies of water of different salt concentrations (salinity) there can exist a pressure difference. This is known as the **osmotic pressure** difference.

Oscillating Water Column (OWC)
A wave-power device consisting of an air chamber in which the front wall has an opening so as to let waves enter inside; the wave action makes the water level in the air chamber – known as pneumatic chamber - to oscillate and the air in the chamber is compressed and expanded generating an air flow through an air turbine.

OTEC
see **ocean thermal energy conversion.**

overtopping
As used in marine energy: Overtopping is the method by which energy from the sea is extracted by allowing waves to impinge on a structure such that they force water up over that structure thus raising its potential energy (hydraulic head), kinetic energy or both. An overtopping device may or may not include a reservoir to contain the overtopped water. Often **axial water turbine**-generators are used to convert the hydraulic head to electricity.

OWC
See **oscillating water column.**

P

park
A number of similar devices arranged into a single group to provide a combined energy output. Also known as a "farm".

peak frequency
The frequency corresponding to the maximum energy spectral density.

peak period
The Wave period determined by the inverse of the frequency corresponding to the maximum energy spectral density.

period
The interval of time between successive occurrences of the same state in an oscillatory or cyclic phenomenon.

phase
See also **amplitude**. Phase is a relative position of two parts of the same wave or between two waves. It is measured as an angle [either degrees or radians].

phase control
Method to obtain optimum oscillatory motion in order to capture a maximum of wave energy. For a simple (single-mode) oscillating system the object is to obtain an oscillatory velocity that is in phase with the excitation force due to the incident wave.

pitch
Rotary oscillatory motion around a horizontal axis in the direction perpendicular to the axis of rotation for roll motion.

polychromatic
Composed of more than one wavelength or frequency.

pneumatic chamber
See **Oscillating Water Column.**

point absorber
Wave-power device for which the horizontal extension is very small compared to predominant wavelenghts, and for which the ability to absorb (and/or radiate) wave energy is essentially independent of the direction of wave incidence.

power
Energy that is capable or available for doing work; the time rate at which work is performed, measured in watts.

power spectral density
The power spectral density is the amount of power contained in each frequency in a wave spectrum.

power chain
See **power train**.

power electronics
Power electronics are used to facilitate the interface between wave energy and grid, or indirectly by providing real and or reactive power compensation and harmonic filtering.

power matrix
See **power surface**.

power surface
Also known as a power matrix. A power surface describes the time-averaged mean power performance of a device in each sea state. A scatter diagram can thus be multiplied by a power surface to produce a mean energy production. The power surface is analogous to a power curve for wind turbines.

Power take-off (PTO)
It is a system incorporated to a renewable energy device that allows energy to be converted from the physical motions of the device to a useful form such as electricity.

power train
Also known as power chain. The power train is a series of components that convert power from one form to another.

practical resource
Resource assessments can be considered in three distinct stages: **Theoretical resource**, **technical resource** and practical resource. Practical resource is the proportion of the technical resource that can be exploited after

consideration of external constraints (e.g. grid accessibility, competing use (MOD, shipping lanes, etc.), environmental sensitivity).

pressure accumulator
Pressure accumulators use an inert gas contained in steel accumulators to store energy in oil hydraulic systems. Gas is stored at high pressure and low volume and the energy is released as the gas expands to a greater volume and lower pressure.

Pressure Retarded Osmosis (PRO)
It is a **salinity gradient energy** conversion technique that uses the **osmotic pressure** difference between seawater and fresh water to pressurize the saline stream, thereby converting the osmotic pressure of seawater into a hydrostatic pressure. **Semipermeable membranes** are used in this process. Other technique is the **Reverse Electrodialysis (RED)**

PRO Process
see **Pressure Retarded Osmosis**

programmable logic controller (PLC)
A system that can be programmed to respond to different input signals and provide control signals to other systems.

PTO
See **Power take-off**.

R

radiation problem
A body, which is at least partly immersed in water, and which is able to perform oscillations, may interact with waves in various ways: If the body is forced into oscillation by external means, it may generate waves on otherwise still water – this is known the radiation problem. See also diffraction problem.

rated capacity
See **installed capacity**. Also the maximum continuous point of operation at which an item of electrical or mechanical equipment is designed to operate.

rated power
The power output of a device under specific or nominal operating conditions. If turbine has a rated power of 1000 kW, that means that the turbine will produce 1000 kilowatt hours (kWh) of energy per hour of operation, when running at its maximum performance.

reflection
The phenomenon of propagating wave energy being thrown back from or bouncing off a surface. Energy reflection is a special case of diffraction.

regular wave
Wave which is periodic and has relatively long wave crests. The regular wave is closely sinosoidal and monochromatic if it is sufficiently low.

relief valve
It is usual to equip an **oscillating water column** wave energy device with a relief valve (or by-pass valve) which allows dissipating excessive pneumatic energy in very energetic seas.

resonance
An increase in the oscillatory energy absorbed by a system when the frequency of the oscillations matches the system's natural frequency of vibration.

response amplitude operator (RAO)
The response amplitude operator (RAO) is a measure of the frequency response of a device relative to the wave causing the motion. RAOs can describe power and amplitude ratios. See frequency response.

reverse electrodialysis (RED)
Salinity gradient energy conversion technique in which ion selective membranes are used in alternate chambers with freshwater and seawater, where salt ions migrate by natural diffusion through the membranes and create a low voltage direct current. Other technique is the **Pressure Retarded Osmosis (PRO)**

Rim turbine
It is a type of **axial flow turbine**. In rim turbines the generator is mounted on the barrage at right angles to turbine blades (this turbine is used in Annapolis Royal in Nova Scotia).

rms
Root mean square. Often used in marine energy to express characteristic values of pressure, water surface level or other physical entities of a given period of time.

roll
Rotary oscillatory motion around a horizontal axis in the direction of longest extension of the immersed body, or alternatively, in the direction of wave incidence.

S

salinity gradient
Energy can be extracted from the sea where large changes or salinity gradients exist. A **semi-permeable membrane** is placed between the two bodies of water. Slowly the less salty water moves into the salty water by osmosis.

Salinity Gradient Energy
Energy that can be captured by exploiting the pressure difference at the boundary between freshwater and saltwater

scatter diagram
Also known as a joint probability distribution. The scatter diagram is a table that shows the frequency of occurrence of different sea states specified by the **significant wave height** and **energy period** (often in parts per thousand).

Scattering problem
The same as **diffraction problem**.

sea state
A numerical measure of the character of the sea for given period of time. The sea state is typically described by its significant wave height and period.

sea trial
Same as **field trials**. Last phase of testing of a concept, typically in prototype stage and scale 1:1 to 1:4. Focus lies not only on conversion efficiency or other limited issues, but on the seaworthiness in general, including mooring

issues, survivability, maintenance and other practical aspects.

selectively permeable membrane
see **semipermeable membrane**

semipermeable membrane
Also termed a **selectively permeable membrane**, it is a membrane which retains the salt ions but allows water through. It is used to extract the power from Salinity Gradient with the **Pressure Retarded Osmosis (PRO)** process.

shallow water
(1) Commonly, water of such a depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water. (2) More strictly, in hydrodynamics with regard to progressive gravity waves, water in which the depth is less than 1/25 the wavelength.

shoreline
The line along which a large body of water meets the land.

shoaling
The influence of the seabed on wave behaviour. Manifested as a reduction in wave speed, a shortening in wave length and an increase in wave height.

significant wave height
The average height of the one-third highest waves of a given wave group or sample. It is usually approximately equal to 4 times the square root of the zero order moment of wave energy spectrum (see **spectral moment**).

spectral bandwidth

The frequency band within which spectral energy density takes significant values.

spectral moment
Characterization of a spectral distribution can be made through the spectral moments. The *n*th spectral moment, m_n, is defined as (where *f* is the wave frequency and *S(f)* is the energy spectral density function):

$$m_n = \int_0^\infty f^S S(f)\, df$$

Significant wave height and **energy period** can be related with spectral moment as:

$$H_s = 4\sqrt{m^0}\ ,\ T_e = m^{-1}/m^0$$

stalling Stalling is a phenomenon during which the air flow leaves the blade surface of a turbine and becomes highly turbulent, so that there is a great deal of vibration and noise and very little conversion of energy to useful form.

stiffness
The restoring force per unit displacement of a spring [N/m].

substation
An electrical installation containing power conversion equipment, such as transformers, compensators, and circuit breakers.

surge
Linear oscillatory horizontal motion of an immersed body in the direction of longest extension. If the body, such as an axisymmetric body, has no particular longest horizontal direction, the direction for surge motion may be specified as the direction of wave incidence.

survivability
A measure of a device's ability to remain intact and operational in extreme environmental conditions.

survival mode
An operation mode for a device that reduces the likelihood of damage being sustained during extreme/uncommon environmental conditions such as storms.

sway
Refers to the horizontal linear oscillatory motion of an immersed body perpendicular to the surge motion.

swell
Wave that has propagated out from the region of wind generation.

System Control and Data Acquisition (SCADA)
An automatic system that allows data collection and control of a system. Such systems are usually accessible by users remote from the system via telecommunications systems.

synchronous generator
An electrical generator that runs at a constant speed and draws its excitation from a power source external or independent of the load or transmission network it is supplying.

T

tank testing
Verification of hydrodynamic properties of a physical scale model of the device/structure under laboratory conditions. Typical sale factors range 10 to 100.

temperature gradient
In the oceans there can often be found a temperature difference between water near the surface and that deeper down. Where this temperature difference occurs over a relatively short distance it can be used to capture energy using a **Rankine cycle**.

terminator
Line absorber which is aligned perpendicularly to the predominant direction of wave incidence.

Technical resource
Resource assessments can be considered in three distinct stages: **Theoretical resource**, **technical resource** and **practical resource**. Technical resource is the proportion of the theoretical resource that can be exploited using existing technology options.

Theoretical resource
Resource assessments can be considered in three distinct stages: **Theoretical resource**, **technical resource** and **practical resource**. Theoretical resource is the top level statement of the energy contained in the entire resource.

Tidal power technologies It includes **tidal range technologies** and **tidal stream technologies.**

Tidal resource
There are two quite distinct categories of tidal resource: **tidal stream** and **tidal range**. The tidal stream resource is the kinetic energy contained in fast-flowing tidal currents, which are generally found in constrained channels. The tidal range resource refers to the gravitational potential energy that can be found in estuarine areas that exhibit a large difference in water height (their 'tidal range') between high and low tides. The technology used to exploit each of these resources is quite different. The two types of tidal resource are generally found in very different locations.

Tidal range resource
The tidal range resource refers to the 'gravitational potential energy' that is created as a result of impounding a large volume of water on the high tide. This water is then passed through low-head turbines once a height difference is created on either side of the impoundment, generating electricity. There are two principal concepts for the design and placement of a tidal impoundment: **Tidal barrage** and **tidal lagoon**.

Tidal barrage
Tidal barrage works in a similar way to that of a hydroelectric scheme, except that the dam is much bigger and spans a river estuary. A hard barrier is placed at a strategic point in an estuary with a high tidal range, thus creating an impoundment upstream of the barrage in conjunction with the banks of the estuary.

tidal lagoon
Offshore tidal impoundment, or 'tidal lagoon' is a completely artificial impoundment that would be constructed in shallow water areas with a high tidal range. See also tidal barrage.

tidal current
The rise and fall of the tides create horizontal movements of water. Usually these are of fairly low velocity, but local topography can greatly magnify them, for example in the straits between islands.

tidal energy
The most notable ways to extract electrical energy from them tides are: a) tidal barrages and b) tidal stream turbines.

tidal range
The vertical distance between the high and low **tide**.

tidal stream
The tides are generated by the rotation of the earth within the gravitational fields of the moon and sun. The relative motions of these bodies cause the surface of the oceans to be raised and lowered periodically, producing the bulk movement of water. Where these moving bodies of water meet land masses, channels or other underwater features they can be enhanced forming a tidal stream.

tidal stream technologies
Tidal stream technologies work by extracting some of the kinetic energy from fast-flowing tidal currents and converting the kinetic energy to mechanical energy before being further converted to typically electricity. To do this they cannot completely block the path of the tidal currents, as otherwise there would be no energy to extract. Instead, they are designed to extract the maximum possible amount of energy whilst still allowing the sea to flow in a normal way – but with reduced energy

tide
The periodic rising and falling of the water resulting from the gravitational attraction of the Moon and Sun and other astronomical bodies acting upon the rotating Earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the range of vertical movement.

time domain
Calculations or control systems that make use of second-by-second data streams operate in the time domain.

trough of the wave
The lowest part of a waveform between successive crests. Also, that part of a wave below still-water level.

Turbine
A machine that generates rotary mechanical power from the energy of a moving fluid, such as water or air.

Tubular turbine
It is a type of **axial flow turbine.** In Tubular Turbine the runner is connected to a long shaft which drives the generator. Tubular turbines are proposed for the Severn tidal project in the United Kingdom.

tuning
Changing a device's natural frequency is known as tuning, and may involve adjusting it's size, shape, mass, stiffness or damping, or some combination of these.

U

useful power
The useful power which is delivered by a wave-energy converter. The difference between absorbed wave power and power that is lost due to dissipative effects, such as friction and viscosity, etc.

V

variable pitch turbine
Wells turbine use symmetrical profile blades with their chords in the plane of rotation. The possibility of the blade being able to change pitch so as to prevent the angle of incidence exceeding some maximum angle has been demonstrated numerically to be more productive than a fixed pitch turbine.

vertical axis tidal stream turbine
A tidal stream turbine mounted such that it rotates about a vertical axis perpendicular to the flow of water.

viscous drag
Drag caused by interaction with viscous fluid such as water.

W

waterplane area
When a body pierces the surface of the water the area of the intersection between the body and the surface is the water-plane area.

wave
Oceans waves are caused by winds blowing over the earth's surface. These winds transfer energy in shear to the water in the seas and oceans. This energy causes waves to form. It is from these waves that carry the energy with no net transfer of water in deep water. Energy can be extracted by marine energy technologies.

wave crest
The wave crest is the peak of the wave. Since many water waves are wide compared with their height. The crests of successive waves proscribe parallel lines on the surface. Measurements of wave energy are usually related to a certain length of wave crest [kW/m].

wave energy
Energy in or from waves. The total energy in a wave is the sum of potential energy, due to vertical displacement of the water surface, and kinetic energy, due to water in oscillatory motion.

wave energy converter
A technical device or system designed to convert wave energy to electrical energy or another kind of useful energy.

wave energy spectrum
A mathematical or graphical description of how a wave state of irregular waves is distributed among the various frequencies.

water depth
Distance between the seabed and the still water level.

wave frequency
The inverse of wave period.

wave height
The vertical distance between a wave crest and the previous wave trough.

wave load
The forces which waves exert on floating, submerged or bottom-standing structures.

wave period
The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point.

wave power
Mechanical power from waves, normally expressed in kilowatts per metre of wave crest length.

wave power device
See **wave energy converter**.

wave power plant
Power plant run by wave energy.

wave-powered generator
Electrical generator run by wave energy.

wave spectrum
Distribution of wave energy as a function of wave frequency.

wave tank
A test facility capable of producing (wide) wave of a known shape and type.

wave trough
The lowest part of a waveform between successive crests. Also, that part of a wave below still-water level.

wave-by-wave tuning
See **fast tuning**.

wave-to-wire model
Mathematical model in the time domain that simulates the energy conversion chain.

wave-rider buoy
A device used to measure wave properties. The buoy rides the waves and estimates the wave positions and directions based on measurements of its own accelerations in different directions.

wavefront
An envisaged plane which is perpendicular to the direction of wave propagation, and which moves with the propagation speed of the wave.

wavelength
The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

watt
A unit of **power** in the metric system, expressed in terms of energy per second. One watt is equal to the work done at a rate of 1 joule per second.

working fluid
A fluid used to absorb and transfer heat energy.

Wells turbine
Air turbine using symmetrical profile blades with their chords in the plane of rotation. This turbine is self-rectifying, that is, its sense of rotation is the same for both of the two opposite air-flow directions.
It is usual to equip the **OWC** wave energy device with such a turbine.

Y

yaw
Rotary oscillatory motion around a vertical axis.

Z

zero crossing period
The average time interval between similar direction crossings of mean water level for a wave record. The zero crossing period can also be calculated from the moments of wave frequency spectra:

$$T_Z = \sqrt{m^0 / m^2}$$

Also called the Mean Spectral Period.

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