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SEC2T (Renewable Energy and Energy Harvesting)

Topic - Ocean Energy

Introduction:

Ocean wave energy is a form of energy that is mainly caused by wind energy. Such waves contain both potential and kinetic energy. For ideal deep water waves, which are not subject to any ground friction, the total capacity of a standard wave of 1 m width is directly proportional to the product of the square of the wave height and the wave period. An assumed so-called standardized spectrum based on the above relation between wave height and wave period allows for the determination of the wave power or energy in relation to height or frequency. For instance, wave heights of 1.5 m at an average wave period of 6.2 s are typical of the German North Sea coast and lead to a significant weight height of 2.11 m and a total wave power of approximately 14 kWm^{-1} wave front. If it was possible to exploit the whole energy of a wave front of the length of the German North Sea coast (about 250 km), theoretically an approximate power of 3.6 GW could be generated.

Because of its considerable energy potential, for several decades, wave energy has been investigated with regard to power generation. However, the multitude of more or less unrealistic proposals that have been elaborated discredited this type of renewable energy. Thanks to the tireless commitment of several research teams over many years, this view now changes gradually. The use of wave energy became a more and more serious and important option for electricity generation on a small and medium scale.

Ocean Energy Harnessing Systems:

TAPCHAN system. Within a TAPCHAN (tapered channel wave energy conversion device) system water advancing over the beach by breakers or swells is conducted into a raised reservoir via a converging inclined channel (Fig. 1). This tapered channel concentrates waves of different frequencies, coming from different directions and simultaneously converts the kinetic wave energy into potential energy. Within this channel the wave height is increased due to the decreasing width. This has the consequence that the water level raises and the seawater eventually spills over the narrow end of the channel into the reservoir whose water level is located several meters above the average sea level. From this storage reservoir, the seawater, accumulated at a higher energetic level due to the difference in height, can flow back to sea via a turbine.

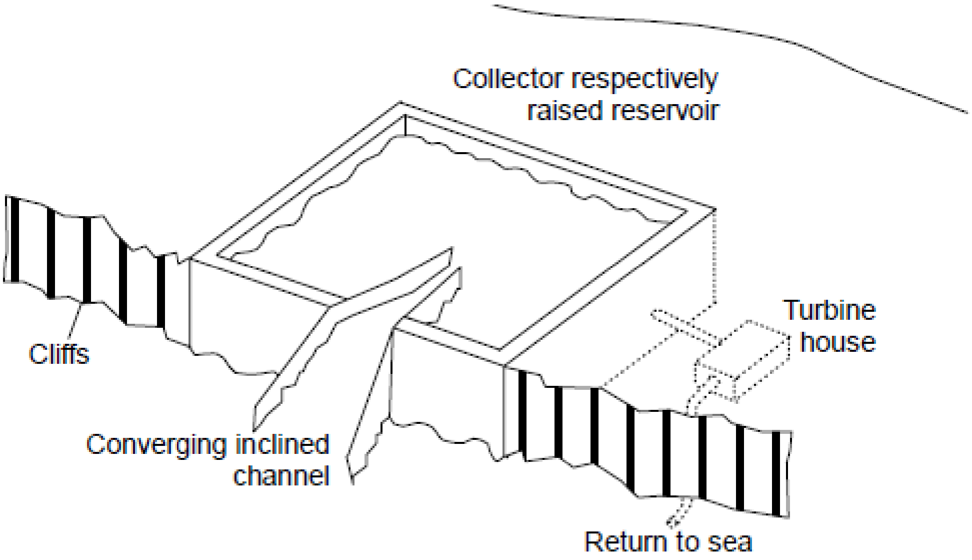

Fig. 1

Due to the storage reservoir this system requires more space than most other wave energy conversion systems. Because of inflow losses (including shallow water effects) only a limited amount of the original wave energy (of deep waters) can be used. However, due to the levelled drainage of the storage reservoir and the applied low-pressure turbine, which is state-of-the-art technology on the markets for power plant equipment, operation of this system is much easier than of most other breaker or wave powered energy exploitation systems. An additional advantage is that the system components applied within this power plant are not subject to open sea conditions, and thus offer a longer technical lifetime. Also the maintenance can be easily conducted. Furthermore, power plant components permanently in motion do not touch the waves, and conversion from kinetic into potential energy is performed by solid reinforced concrete elements. The plant thus also withstands bad weather conditions. It is moreover beneficial that such plants are easily accessible from the shore. As fresh seawater is continuously conducted into the storage reservoir the latter is also suitable for fish farm operation. When compared to a straight overflow edge, parallel to the wave crest, a considerable benefit of such wave or swell-powered generators provided with a tapered channel is that basically all waves reach the required height at some point in order to fill the raised reservoir over the narrow end of the channel.

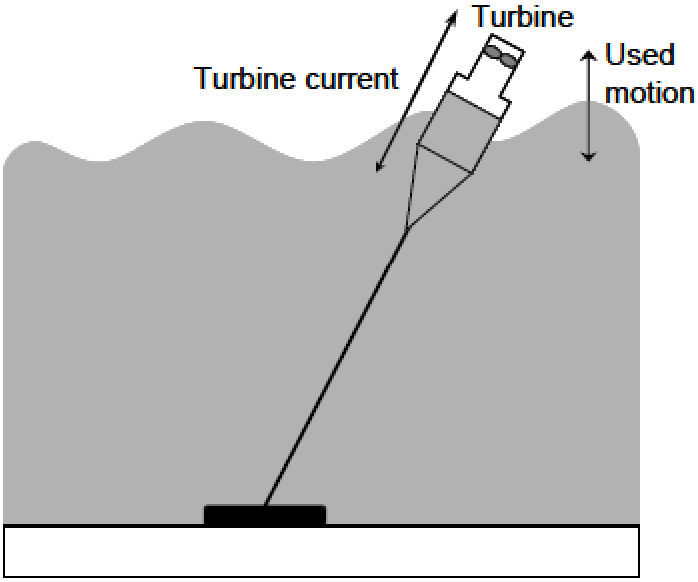

Fig. 2

OWC buoy. The OWC (oscillating water column) buoy is based on a vertical tube submerged so deep into the seawater that it is below the level where wave motion occurs. This buoy contains a water column that cannot directly follow the buoy or wave motion and is therefore caused to oscillate by motion. A water or air turbine installed inside the tube, located inside the upper part above sea level, rotates due to the upward and downward movements of the water column and drives a generator to generate power. A major problem of the OWC system is to transmit slow motion into faster motion that can be used for power generation. Since this transformation is technically only possible in conjunction with mechanical and hydraulic system elements that are furthermore very costly, this technology is not suitable for the small-scale systems, for fundamental reasons. For OWC systems, wave motion is thus transmitted by means of air; usually Wells turbines are applied (Fig. 2).

Lighted buoys, operating according to the OWC principle, have been applied on sea for more than 20 years. The small air turbines installed inside such buoys have proven to be durable and cost-effective. Due to the fast movement of the turbine water does not penetrate into the turbine ball bearings; therefore corrosion is prevented.

Energy from Tide:

In association with the rotation of the earth, the gravitation forces of the moon and the sun (i.e. movement and gravitation of planets) periodically alter the water level of the ocean. In the open sea tide waves are characterized only by height differences of a little above 1 m. Yet, the mainland has a braking effect on the tide wave and generates backwaters at the shoreline, so that maximum water level changes of 10 m and more are possible. In certain coastal areas, such as bays and river estuaries, the tidal range may rise up to 20 m due to resonances or funnelling.

Harnessing high and low tide streams. Since harnessing the energy of the sea by utilizing a bay to be separated by a dam, is connected with enormous consequences for the natural environment, lately, exploitation methods based on the high and low tide stream, and thus on water motion caused by low and high tides, have been investigated. However, a major disadvantage of such systems is the comparatively low energy density of the ocean currents.

There are only little pressure differences in such currents with the result of relatively slow current speeds and big current cross-sections. Therefore turbines suitable for low and high tide streams must be developed, such as the large Savonius or Darrieus rotors, which perform satisfactorily under the described conditions. Fig. 3 illustrates the example of a corresponding project study in comparison to an offshore wind power station.

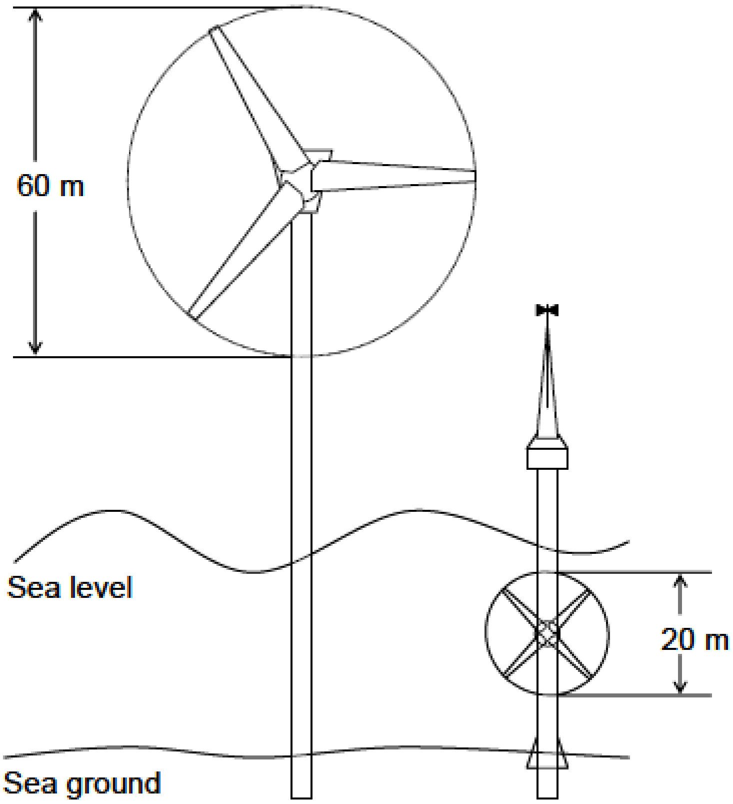

Fig. 3

Ocean Thermal gradients. The major portion of the solar insulation is stored as heat in the atmosphere and in solid or liquid components of the earth's surface. About 20% of the total radiated energy from the sun is converted into heat solely in tropical oceans. From a technical viewpoint it is possible to utilize this heat. Yet, due to the large water surfaces located within the equator belt, the theoretical potential of this option is relatively high.

Fig. 4 shows the typical water temperature variations of equatorial oceans in relation to water depth. According to this illustration, the temperature varies roughly between 22^0 and 28^0C (within the course of a year) within the water layer close to the surface. The temperature of the deeper layers remains more or less constant over the entire year and is relatively low when compared to the water temperature at the surface.

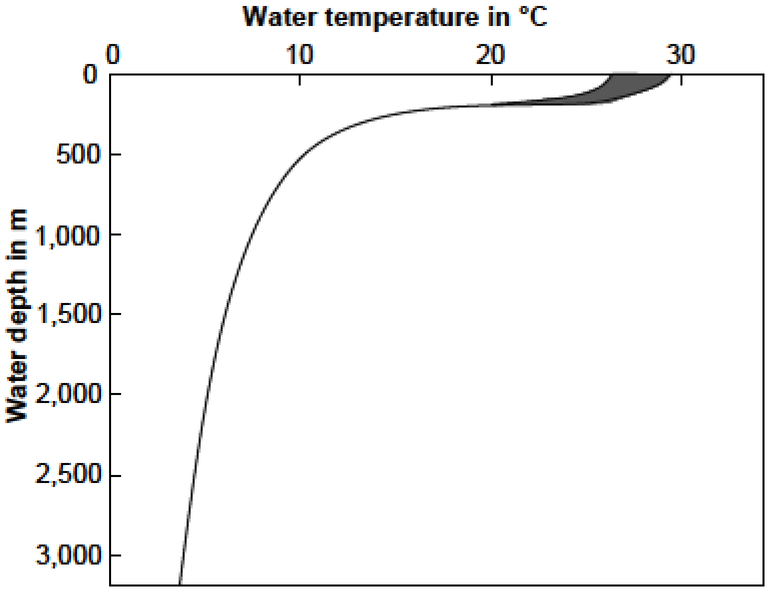

Fig. 4

Topic - Geothermal Energy

Introduction:

Apart from the energy resulting from solar energy and the interaction of planet gravitation and planet motion, the heat stored in the earth is another renewable energy source available to human mankind. In this e-report the principles of this type of energy supply are described and discussed.

Principles:

Earthquakes cause sound waves occurring as compressions of matter (compression waves) or as movements perpendicular to the direction of propagation (so-called shear waves). They can be measured with receivers (seismometers) distributed throughout the overall globe. By tracing and analysing these sound waves, a layered structure of the earth can be determined. The crust of the earth, or the top layer, reaches below the continents to a depth of approximately 30 km; below the oceans the earth crust only has an average thickness of around 10 km. The Mohorovicic discontinuity separates the earth's crust from the mantle. By going from the crust to the mantle, the velocity of seismic compression waves increases. The earth's mantle is solid, and reaches down to a depth of up to approximately 3000 km. It surrounds the core of the earth, which is assumed to be liquid, at least in its external part (approximately 3000 to 5100 km). The core shows no shear waves propagation (Fig. 5).

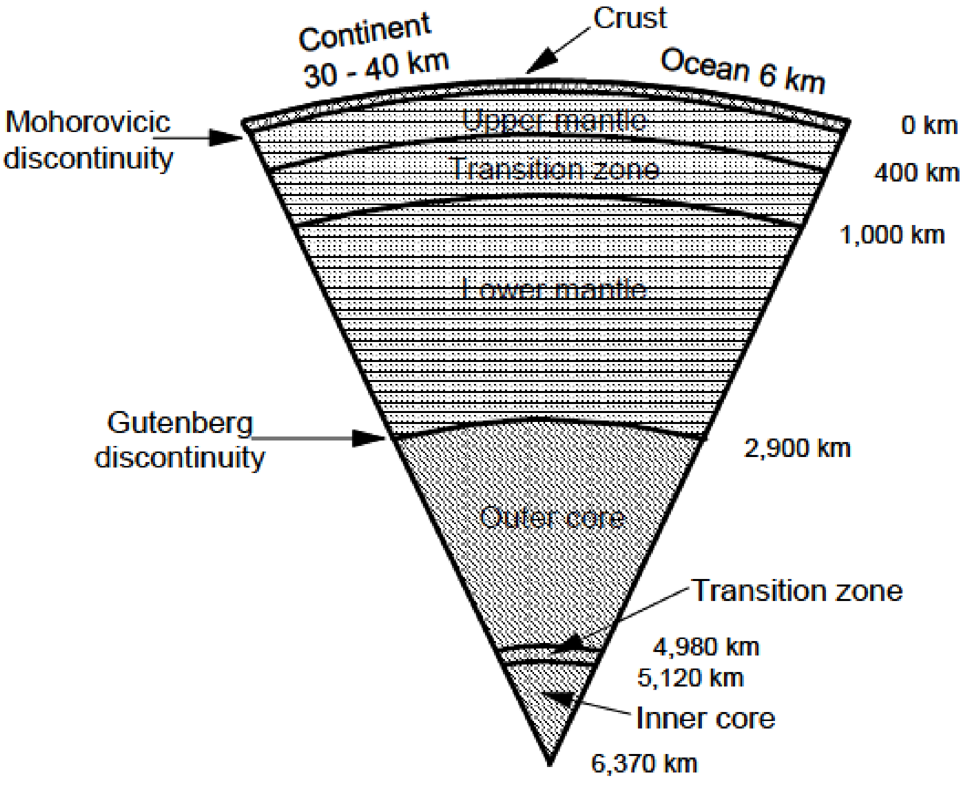

Fig. 5

The upper crust of the earth up to a depth of approximately 20 km mainly consists of granite types of rocks (approximately 70% SiO_2, approximately 15% Al_2O_3 and approximately 8% K_2O/Na_2O). The lower crust primarily consists of basaltic rocks (approximately 50% SiO_2, approximately 18% Al_2O_3, approximately 17% $FeO/Fe_2O_3/MgO$, and approximately 11% CaO). The mantle below mainly consists of peridotite with the mineral olivine. It is assumed that the earth' core consists of iron and nickel. The assumptions about the structure of the deep earth are – among other studies – based on spectral analyses of extraterrestrial bodies, composition of volcanic plutonic rocks and modelling of geophysical measurements.

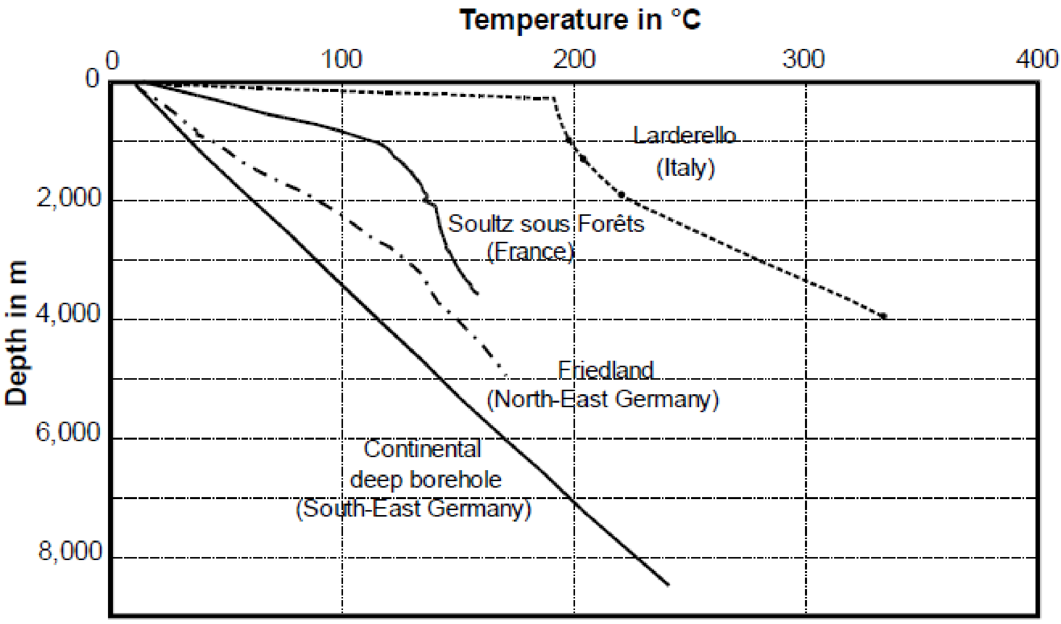

Fig. 6

Temperature gradient. The temperature gradient within the outer earth crust which has been measured in deep wells, on average is 30 Kkm^{-1} (Fig. 6). In geological old continental crustal shields (e.g. Canada, India, South Africa) lower temperature gradients can be observed (e.g. 10 Kkm^{-1}). In contrast, much higher gradients are measured in tectonically active, young crust areas, e.g. at the boundaries of lithosphere plates. The temperature gradient in the earth's mantle can be estimated from its geophysical properties. The temperature has to be below the melting point of the mantle's siliceous rocks, even taking into consideration the pressure dependence of the melting temperatures. The maximum temperature gradient in the earth's mantle is therefore estimated to be in the order of 1 Kkm^{-1}.

Geothermal Resources:

The natural surface heat flow density of approximately 65 mWm^{-2} cannot be used directly at the surface of the earth due to economic reasons. On the other hand, hot water in depths of sometimes only a few hundred meters, with increasing temperatures up to depths of several thousand of meters, hot wells at the surface of the earth, and the well-known volcanic areas demonstrate the existence of such heat, and thus the geothermal energy potential.

Above 130^0C geothermal reservoirs can be used for electricity generation. Basically the provision of electrical energy is also possible at temperatures below this temperature range; the coldest geothermal power plant of the world located in Neustadt-Glewe/Germany operates at a temperature level of approximately 98^0C; but temperatures above 130^0C are necessary to get sufficient efficiency to convert the earth's heat to electrical power. Geothermal energy of temperatures above 150^0C is already utilised in several locations (i.e. Italy, New Zealand). Usually, geothermal power production is independent of the time of the day or the season and the local weather conditions. The reservoirs can be used economically for base load energy provision and in most cases in an environmentally friendly way. However, the appropriate geological requirements have to be met. This is only the case to a limited extent worldwide.

Geothermal Well Drilling:

Due to severe drilling conditions at high temperatures especially in geothermal fields, or for the drilling of hard abrasive rock types (like for Hot-Dry-Rock reservoirs), the drilling of geothermal wells is usually more challenging compared to oil and gas wells. Therefore within the following explanations the basics of deep well drilling is discussed.

The technique for the drilling of geothermal wells is very similar to the drilling of oil and gas wells. Almost exclusively, the rotary drilling technique is applied. The drilling tool is in most cases a tricone bit. The bit is rotated via the drill pipe, a steel pipe of much smaller diameter than the bit, by a rotary table in the floor of the drilling platform. The rock cuttings are transported to the surface by “drilling fluid”, which is pumped down through the drill pipe and ascends in the annulus between drill pipe and borehole wall. Due to the relatively large cross sectional area of this annulus high flow rates of the drilling mud are required to achieve the flow velocities necessary for transporting the rock particles.

During drilling the weight of the drill pipe is hanging on a hook in the tower of the drilling rig. A string of heavy thick walled large diameter drilling collars sitting on top of the drilling bit provides the load for the support of the drilling bit. The weight of the collars and their large diameter stabilise the drilling direction, and cause a vertical trend of the well. Further stabilisation of the drilling direction and smoothening of the borehole wall is provided by reamers installed between the drilling collars and equipped with hard metal cylinders rolling around the borehole wall.

Topic - Hydroelectric Energy

Introduction:

Due to gravitation water flows within a stream or a river from a higher geodesic site to a lower geodetic site. At both sites the water is characterised by a particular potential and kinetic energy which is different from each other. In order to identify this energy difference of the outflowing water, in an approximation, a stationary and friction-free flow with incompressibility can be assumed. With these preconditions the hydrodynamic Bernoulli pressure equation can be applied.

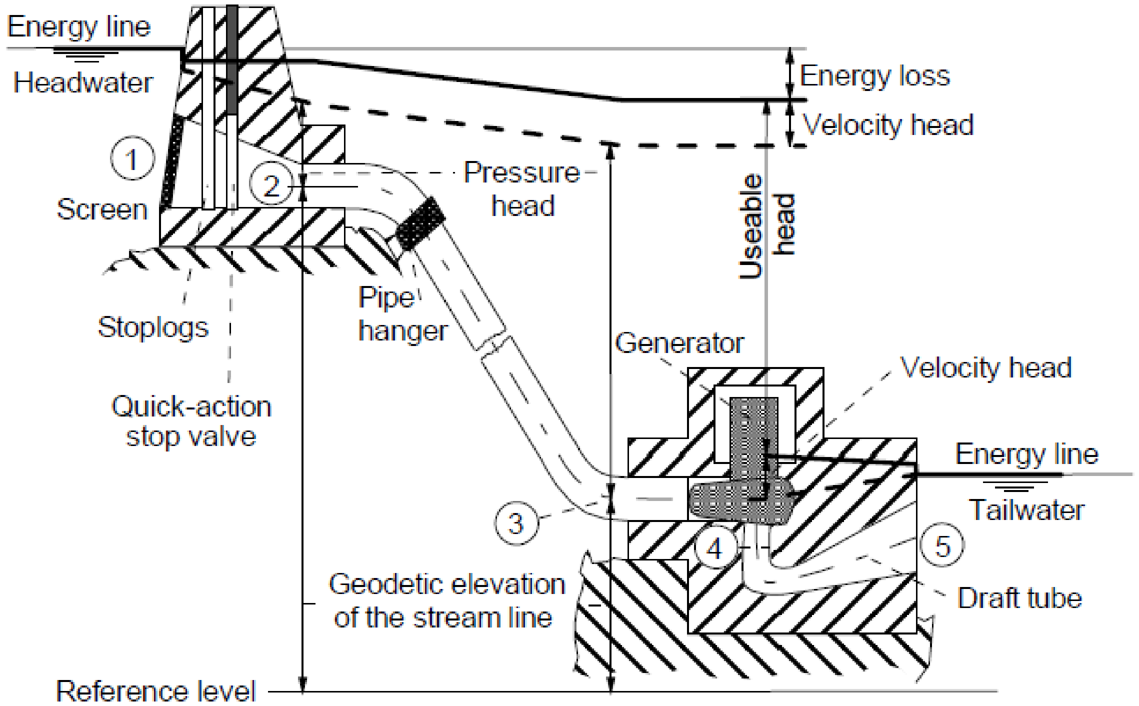

Fig. 7

In Fig. 7 the lines enable the graphic representation of the Bernoulli equation. The dotted line represents the geodetic level of the water flowing through the hydroelectric power station. The so-called energy line is at the top left corner of the diagram. It shows the locations and respective energy losses. The distance to the broken line below the energy line corresponds with the kinetic energy of the water. This becomes apparent at the intake structure, where the water flow increases due to the narrowing of the cross-section and the kinetic energy therefore increases at the same time. The difference between the geodetic level and the broken line is the pressure energy level.

Schematic Layout:

The components described in Fig. 8 are required for the technical conversion of energy in flowing water to electricity in a run-of-river power station. These components are the water intake at the headwater, the weir, the inlet and outlet of water to and from the turbine, the outlet at the tailwater, and the powerhouse with machinery and electrical equipment. These system elements are usually combined in the dam that enables the use of the head and the powerhouse.

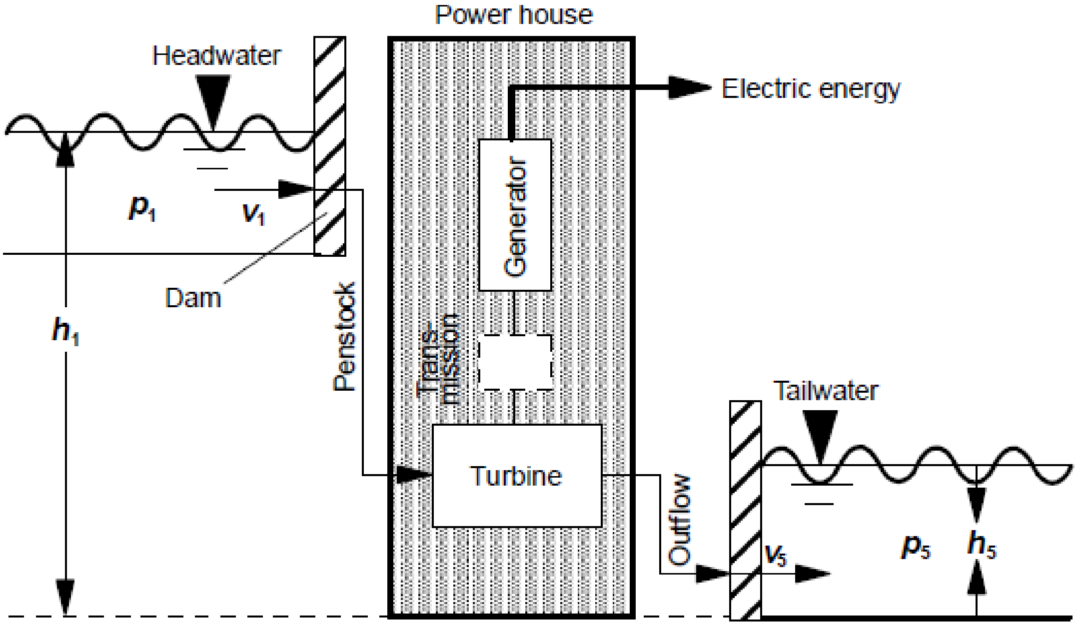

Fig. 8

Two system components are the main elements of the actual energy conversion within a typical hydroelectric power station. Together with the turbine that draws the energy from the water and converts it into mechanical energy, the second component is the generator for further conversion into electrical energy, and thus into the final product. Depending on the plant configuration, a transmission is additionally required if turbine and generator rotational speeds are different or if both components are not on the same axis. In smaller plants the transmission is often replaced by a simple belt drive.

Categorization:

Hydroelectric power stations can be divided into low, medium and high head power stations, additionally run-of-river power stations and hydroelectric power stations with reservoirs can be distinguished. The differences between the various types are not clear-cut; in practice, there are a number of combinations and mixed types. In the following the significant aspects of the different types are discussed briefly.

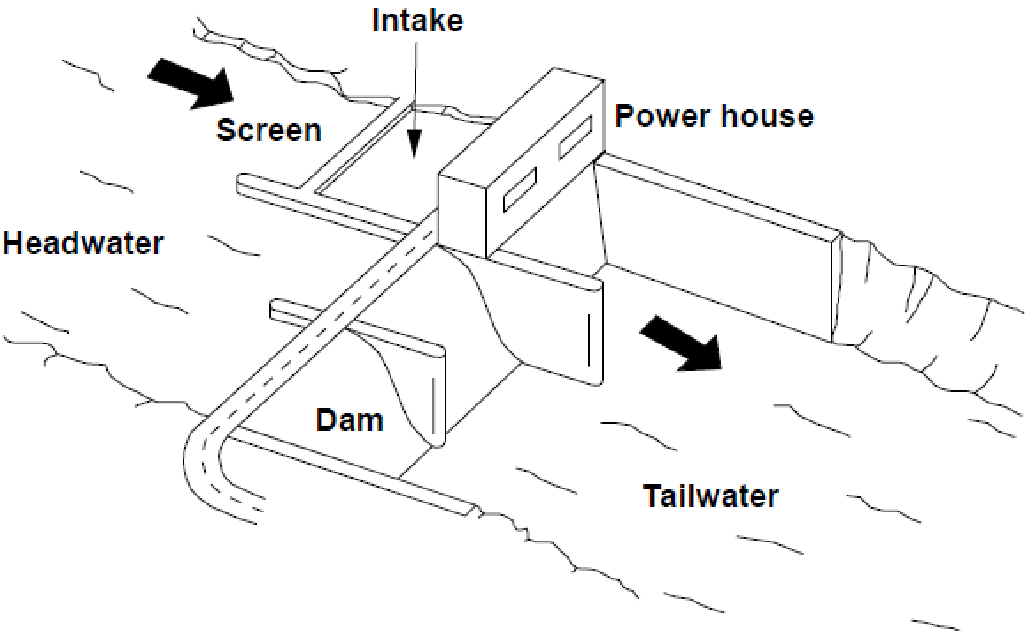

Fig. 9

Low-head plants. Low-head plants harness the flow of a river, in most cases, without any storage; they are typical run-of-river power stations. They are characterized by a generally large flow and relatively low heads up to approximately 20 m. For example most of the run-of-river power stations in Germany are lowhead plants. Depending on the plant layout, diversion-type and run-of-river power stations (Fig. 9) can also be differentiated.

Medium-head plants. The medium-head plants exclusively built as barrages mainly consist of a dam and a powerhouse at their base. Thus these plants use the head created by the dam, which can be between 20 and approximately 100 m high. The average discharges used by the turbines are partly obtained by appropriate reservoir management. If medium-head plants are built as diversion-type power plants, they sometimes use water from one or several streams, which is led through channels, free-flow or low-pressure tunnels to a compensation and storage reservoir and from there through pressure tunnels or shafts to the powerhouse.

High-head plants. High-head plants have a head of between 100 and 2,000 m. They can be found in low and high mountain ranges and are normally equipped with a reservoir to store the inflowing water. The flow rates are relatively low. In contrast to the low-pressure plants, where the available power is a result of large flows, power is a result of high heads in this case. As the available water often comes from very small catchment areas, the effort it takes to capture water in the reservoirs is sometimes quite significant. Often, small streams are diverted from parallel valleys into the valley with the reservoir. High-pressure plants can be planned as diversion-type or dam power stations. Diversion-type high-head power stations divert the water from the reservoir through tunnels or low pressure pipes via a so-called surge tank (reduction of water hammer); from there it flows to the turbine through penstocks or high pressure tunnels. The entire plants can be built into the neighbouring rocks (cavern power station). In the case of dam power plants, the power station is at the foot of the dam. The large reservoirs of the European Alps are all part of diversion type hydropower schemes. The power stations themselves are often far away from the reservoir in the lower valley of the main river.

Water from the reservoirs is sent to the power station for power generation according to demand. A distinction is made between daily, weekly, monthly and annual reservoirs plus inter-annual reservoirs. Annual reservoirs, for example, store the water from snowmelt in spring and summer in order to produce electricity in the following winter to cover the peak demand. The higher the available head, the smaller the reservoir may be, still producing at the same amount of energy.

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Reference:

Renewable Energy: Technology, Economics and Environment, Martin Kaltschmitt, Wolfgang Streicher and Andreas Wiese, Springer

(All the figures have been collected from the above mentioned reference)

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