HYDROELECTRIC PLANTS

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Introduction

The main concept hydroelectric plants are based on is to transform the potential energy of resting mass of water and/or the kinetic energy of a water current into mechanic energy. Subsequently this energy will be converted into electric energy.

Different types of plants

Hydroelectric plants are subdivided into: big hydroelectric plants (or simply hydroelectric plants) and minor hydroelectric plants (or mini-hydroelectric plants). This subdivision depends on the power installed inside the plant and can take 10 MW as a reference value (actually in Italy minor hydroelectric refers to a maximum power of 3 MW). This subdivision is usually reflected on different types of plants: while large hydroelectric plants usually require wide surfaces to be submerged, with a significant environmental and social impact, small hydroelectric plants perfectly integrate with the local ecosystem (it directly exploits the river current).

Hydroelectric power plants are also marked by great flexibility of use. Thanks to the modern automation systems, a few minutes are enough to make the power plant pass from the stand-by to the full power state. Thanks to this peculiarity, hydroelectric power plants are faster than thermoelectric power plants in increasing their production of electric energy during peak consumption hours.

Therefore, the hydroelectric production process is convenient not only from the economic and environmental viewpoint, but also from the viewpoint of operating efficiency. Hydroelectric plants can also be defined according to the type of plant, i.e. regulated flow plants or flowing water.

Regulated outflow power plants

These plants are natural water basins (lakes) or artificial lakes (like many tanks) and sometimes the capacity of water basins increases by means of barriers (many times barriers are dams that are tens of metres high). It is possible to modify the quantity of water used by the power plant. Today these are the most powerful and exploited plants, although they have an environmental impact. They can be used as energy “accumulators” during peak hours by pumping water at night.

In general these plants have more than 10 MW power and reach an extremely high power: for example, Itaipu plant in Brazil has a basin of 1,460 square Km extension (4 times as much as Garda lake).

Flowing-water power plants

Flowing-water power plants were much more used at the beginning of the last century, above all to activate machine tools in some workshops. The potential of these plants today is less exploited than it could be. Moreover the environmental impact of these plants can be limited. The flow into these plants cannot be regulated, therefore the maximum capacity coincides with the watercourse capacity (except a portion, called minimum vital flow, that is needed to safeguard the ecosystem). Therefore the turbine produces energy according to the watercourse availability: if the watercourse is dry and the water flow diminishes under a certain level, the electric energy production stops. In Switzerland flowing-water power plants satisfy the basic need for electric power.

How is a plant made

A hydroelectric plant usually includes five elements: a water collection system, a penstock a turbine transforming potential energy into mechanic energy, a generator converting mechanic energy into electric energy and a control system regulating the water flow. After being used, water is returned to its natural flow without undergoing any transformation from the viewpoint of its chemical and physical properties.

The collection system is mainly a barrage or a dam. It has to comply with very rigorous building and operating principles regulated by the law and, in the case of larger plants, monitored by the National Dam Service. The surface levelling hoses and the bottom outlet ensure a controlled management of the water in the basin. According to the characteristics of the area where the barrage is built, different types of batters (small size barrages) or dams apply. After it has been collected, the water is conveyed into a turbine through pipes. These pipes start from the place where the water is collected and take the water to the plant where electric energy is produced. They are inclined and consist of round steel tubes (they also have valves on the head and foot that allow them to block the water passage).

The variables determining its capacity are the available head and the rate of flow. The first is the difference between the level at which the water is before entering the collection system and the outlet level. The rate of flow is the volume (measured in cubic metres) of water passing through a section in one second’s time. In order to calculate the hydroelectric potential of a site, it is necessary to know the flow variation during the year and the available gross head. Sometimes the hydrographic services install a measurement unit and collect the data about the previous flowing rates. Should the hydro-geological data be unknown, it will be necessary to measure the flow rate for one year. Each turbine contains a water intake and distribution device leading it to an impeller where the potential energy is transformed into mechanic energy. Moreover, turbines can be divided into impulse turbines and reaction turbines. In the former the whole transformation takes place inside the water distribution device and therefore they are preferred when the available head is higher (up to 1,000 metres) and the rate of flow is limited.

If the available head is lower (up to 200 metres) and the rate of flow greater, a reaction turbine is preferable to exploit the action of the impeller as well. Solidly fixed to the turbine shaft, a generator transforms mechanic energy into electric energy. Each generator includes a moving rotor, upon which a magnet is installed, and stator, a fixed component. The magnetic field generated by the rotor transmits a electromagnetic power – electricity – to the copper coils in the stator. Through suitably dimensioned copper cables, the electric energy, which is originally characterised by a 5,000 volts voltage, goes from the generator to the transformer. Here the voltage is increased up to

150,000 volts before the electricity is conveyed into the distribution network. The whole hydroelectric system is governed, controlled and protected by electronic devices monitoring the production process and intervening in case of failure and/or anomalous operation, stopping the plant immediately. Over the last years, thanks to I.T. and telecommunications, almost all plants are remotely operated from a limited number of control centres supervising all the necessary operations to allow the plants to work correctly.

Barrages

Barrages intercept the watercourse in a specific area. There can be two different types of barrages which differ according to their dimensions: dams or weirs.

Dams. Dams are high works that, as well as intercepting the watercourse, create a tank that is useful to regulate the flow rate. They can be hundreds of metres high. Dams can be made of concrete or melted materials.

Weirs. Weirs are modest height works that usually retain the high water within the river bed. Their maximum height is ten metres. They can be fixed or mobile, according to the bed configuration, the maximum flow rate and the need to avoid, during floods, excessive overflowing which would be dangerous in the area above the weir. Fixed weirs are made of masonry or reinforced concrete and are bound to be overcome by water during floods or flow rates that are higher than what the plant can bear. This is why they are usually shaped to avoid erosion. Mobile weirs have a fixed part, made of masonry or reinforced concrete, and a mobile part (called bulkhead) usually made of steel.

Small plants, small impact

In order to overcome the problems regarding the protection of the environment which the realization of hydroelectric power plants in areas that are particularly vulnerable and sensitive involve, the trend of the past years has been to progressively abandon the construction of large plants with a heavy impact on the environment, in favour of small sized hydroelectric power plants, the microhydro plants, which are small hydroelectric power plants with powers that are less than 100kW. These power plants are built without storage tanks or water collection areas, and can exploit differences in levels of only a few metres, enabling the production of energy even in isolated areas that are normally not served by the national energy supply network, as for example isolated inhabited locations, farms and shelters. This type of water resource offers the concerned mountain communities the possibility of a direct control of its management and use. The energy that is produced is exploited on site with immediate advantages for the local populations and without necessarily setting up imposing electricity power lines. For plants with a limited power, the intake of water is quite limited, changes in the course and the flow rate are negligible and the water that is used is returned immediately downstream of the hydroelectric power plant. The characteristics of these plants seem to be most suited to exploit the potential of the streams that are fed by waters from melting ice in a capillary manner, in isolated mountain areas that are not well served by the national network. At present a law proposal is being examined, which will also allow the inclusion of micro-hydro power plants in the net metering network, which is an exchange system with the

Italian national electricity network, which enables the input of energy when one's production has an excess and to draw energy when one's production is not sufficient. At present this method is applied only in the case of energy produced by private photovoltaic plants.

Environment and territory

Just like other types of renewable sources, hydroelectric energy is characterised by remarkable advantages as compared to the production of electric energy from fossil fuels. To begin with, it is a renewable and endless source. Secondly, emissions of polluting substances into the air and water are virtually absent, since no combustion process is involved. In particular, carbon dioxide (CO_2) emissions are reduced by 670 grams for each kW/h of energy output. Other advantages are: a low dependence on ester energy sources, source diversification and the regional re-organization of energy production.
Moreover, mini-electric plants, in many cases, thanks to their hydraulic arrangement, create many advantages to the watercourse (in particular to the regulation of floods in water streams, especially on the mountains characterized by soil deterioration), and can efficiently contribute to the protection and safeguarding of the territory. In some cases, the artificial lake that forms as a consequence of a weir o dam can improve the surrounding area, by allowing the development of tourist, sports and productive activities that can coexist together with hydroelectric exploitation.
The chance to accumulate water and then regulate its flow downhill can also contribute to reduce floods and encourage a better use of water resources, which are becoming more and more precious and rare.

Really clean energy?

Hydroelectric power suggests, in our mind, the idea of a clean source of energy, that is eco-compatible and especially a source of energy that is renewable. Actually, a large power plant has problems in connection with the environmental impact, problems of an aesthetical nature, electromagnetic pollution and overload of the ground. Water intake decreases the amount of water in the streams and rivers downstream from the power plant and provokes disorders in the river ecosystems with severe damage for the fish- and naturalistic heritage. According to the law, water intake must not exceed a percentage of the natural flow, and what is called the "minimum vital flow" must be guaranteed, in order to protect life and the ecosystems of the river or stream. Actually during the periods of draught, long stretches of the waterways become quite dry, with consequent damages to the environment. The negative effects are not only limited to parts of the river downstream of the power plants, but may be noted in the entire water supply network, a decrease in the flow rate of the waterways consequently leads to a greater concentration of the pollutants in the water and also in the underground water table that they supply water to.
With regard to the future development of hydroelectric power, in Italy, as in most of Europe, this type of resource has been almost completely exploited, i.e. the hydroelectric power plants have been built in almost all the locations where there were ideal conditions to exploit the kinetic energy

of water precipitating towards the valleys from the mountains. It is therefore difficult to increase the number and the power of the existing park of hydroelectric power plants. In other large regions of the world, this form of energy is available in large amounts, and still has not been exploited. It is the case of Africa, where as a result of the low consumption of energy per person and the low level of wellbeing, this type of energy can become precious and important to support the economic development of these populations.

A second limit of the hydroelectric power plants are the vast areas of territory that are often occupied and flooded by very large dams, which are built for the purpose of accumulating the water that is necessary to move the turbines constantly. It is therefore necessary to modify the original plan of the territory and the natural flow rate of the rivers and streams, which, in some cases, causes environmental impacts on the ecosystems and economic impacts on other agricultural or industrial activities.

Therefore large hydroelectric plants with a reservoir require opportune assessments with regard to the impact on the environment, in order to guarantee the absence of interference with the natural environment. Underground Hydroelectric Power plants partly eliminate the aesthetical problem, however there is the problem of the disposal of the excavation materials, and these plants can influence underground water circulation.

Visual impact

With reference to the visual impact of large hydroelectric plants, they are difficult to hide and quite eye-catching. This is why it is necessary to carry out a careful assessment of the plant on the territory, by also making an aesthetical assessment. Any element in a plant (bars, intakes, power plant, restoration works, electrical substation) can determine a change in the site visual impact. In order to reduce the impact, some elements can be disguised with the vegetation; it is possible to use colours that better integrate with the landscape and build a part of the installations underground (i.e. the power plant).

Acoustic pollution provoked by a power plant is usually generated by turbines and turn multiplication mechanisms. At present the noise can be reduced up to 70 decibels inside the power plant, to imperceptibles levels from the outside. For example in Fiskbey 1 power plant in Norrkoping, Sweden, there is a maximum internal noise of 80 decibels and 40 decibels outside, at 100 m distance. This is a totally acceptable value. Noise is therefore easy to sort out.

Relation with the ecosystems

The relation with the ecosystems is fundamental when designing a hydroelectric power plant. Two aspects are strictly linked to the collection of superficial water and can provoke two different impacts:

- Impact related to the variation (reduction) of the water quantity, with possible consequences for the users, that could argue about the use of water and impact on aquatic fauna;

- Impact related to the change in the water quality as a consequence of quantity variation (i.e. higher concentration of pollutants) and as a consequence of vegetation change on river banks.

If a dam for a basin power plant is built, the consequences will be the following ones: above the barrier a reservoir will form and therefore there will be running water (lothic water) moving in still water (lenthic water), with a longer time needed to exchange water and a possible impact on the ecosystem. Underneath the barrier, until the area where the water used by the plant is released, the watercourse may be dry for some periods of time unless a continuous release is guaranteed so that the river has a suitable minimum flow rate. The minimum flow rate (to be guaranteed according to the law), that ensures the natural development of all biological and physical processes, is called “minimum vital outflow”. All these aspects have to be taken into consideration during the impact assessment. This is why some choices are made during the design phase and precise precautions are taken to avoid any type of damage to the ecosystem. The reduction in water flow rate does not have to be excessive, and it is necessary to respect the minimum vital outflow value, since otherwise it is possible to damage the deposit, incubation, growth and transit of fish. With regard to the latter aspect, it is necessary to take into consideration the movement of fish that go up the current and the fish that go down the current, by building the adequate passages, installing the most suitable nets to prevent the fish from entering into the intake areas and get into the turbine (some types of turbines can kill the fish). When a dam is built to supply a hydroelectric plant, it is necessary to think about the different ways water can be used: drinking water, agricultural water or industrial water. The size and management of the dam must be compatible with all these needs, by optimising the use of water as a resource, since in some regions water is not sufficient to satisfy all these needs.

Dams and the local climate

The presence of a dam influences the microclimate of the territories all around due to the large mass of water that collects upstream of the dam. In fact water has a high thermal capacity, a parameter that indicates the quantity of heat required to raise the temperature of a body 1°C, which means that water absorbs a great amount of heat, which it takes from the atmosphere, in order to warm up. In summer therefore the water absorbs great quantities of heat from the air thus mitigating the atmospheric temperature. The opposite takes place in winter, when the water cools, releasing a large amount of heat in the atmosphere. Near artificial reservoirs, in summer the atmospheric temperature is lower than in the surrounding areas, because the water takes away the heat from the air. In winter the microclimate in the lake area will be warmer than in the surrounding area, because the lake gives off the heat it has stored to the atmosphere which becomes warmer. The extension of the area concerned depends on the volume of water that the dam can hold back.

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