EUSUSTEL

European Sustainable Electricity
Comprehensive Analysis of Future European Demand and
Generation of European Electricity and its Security of Supply

WP3:
Electricity generation technology and integration system

Hydraulic electricity generation

C.Ngô, I.Lescure, G.Champvillard

Contents

1. Introduction

Hydraulic is a flexible and adaptable technology which provides 13 % of electricity in the European Union. Out of that, 1.5 % is provided by small-size hydraulic plants (with a power smaller than 10MW).

Hydraulic power is a low energy density resource: in order to produce 1 kWh in a plant with an efficiency of 85%, 10 tons of water should fall from a height of 40 meters.

The amount of electricity that can be produced by hydro-electricity generation depends on two things:

1. The rate at which the water flows;
2. The difference in height between the top of the dam or reservoir and bottom reservoir, below the turbine. This is called the head of water.

Hydro-electricity generators transform the kinetic energy of moving water into electricity. The system is simple: a continuous flow of water is going through a turbine, induces its rotation and generates mechanical power. This turbine is connected to an alternator which generates electricity which is distributed on the grid.

Water flows from a dam or reservoir to the turbine through a huge pipe called penstock. The water passes through a spiral-shaped pipe making it spin. The spinning water induces the rotation of the turbine.

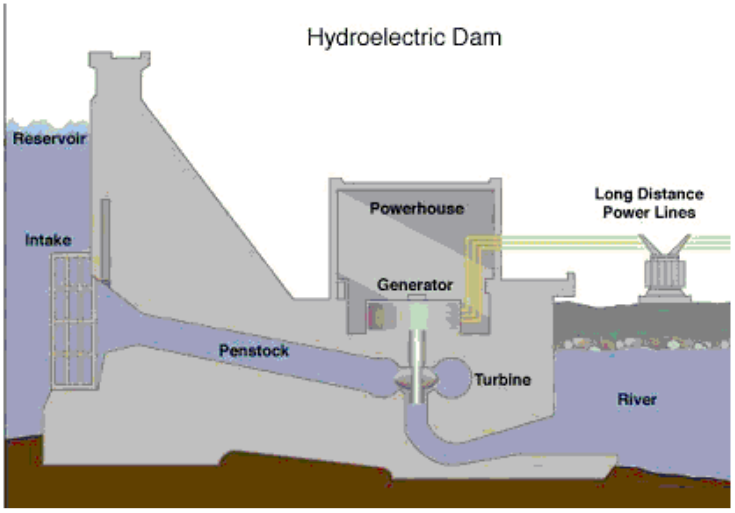

Figure 1 Hydropower station

In order to produce large amounts of electricity, there are two extreme situations: big flows (several thousands m^3/second), or great height of fall (several hundred of meters). In both cases it requires to have enough water but this depends on catchments basin and pluviometry. Situations where both a great height and big flows occur at the same time do not occur often, but when these conditions are met, large-size hydraulic dams can be built. For example, the large dam built in China “3 gorges” will have a power of 18 GW.

In Europe, it rains all over the year and this is benefic for the monitoring of electricity generation. All European countries cannot build dams because mountains are needed and an adequate supply of water from rain or snow is required for the hydro-electricity generation plants to be operated. If drought occurs, power production can be severely affected. Thus, countries using hydro-electricity need alternative electricity supplies for such events (mainly coal, oil or gas stations).

Large dams, which have containment basins, can be used for electricity storage. The upstream water reserve can be used to store the surplus of energy by pumping of downstream water.

Therefore, during off-peak hours, the water can be stored and used during peak hours. Consequently, lakes and dams are not only a water reserve, but also an energetic reserve. They are essential for adjusting the production on the electric grid.

It is the only energy source that can be used for others purposes: when a hydro-electricity water storage dam is built, the water of the dam can be used as a source of drinking water and for recreational purposes such as boating and fishing. Dams represent opportunities for the development of activities, favour agriculture and some of them can be used to control rises in water level or floods. Although dams prevent the natural flushing out of a river during a flood, they also control flooding downstream in times of high rainfall and snowmelt. In France, there are regulations requiring the electric companies to keep some water reserve to fulfill other needs like watering.

Flexibility and the possibility to quickly start producing electricity are among the main qualities of hydraulic plants, which permit to supply peak demand and balance the electrical network. To meet any changes in electricity demand, hydro-electricity generators can be stopped and started in few minutes. As a matter of comparison, it can take up to eight hours for fossil-fuel station to shut down, and a nuclear station can need up to several days.

Dams permit also to store potential energy of water, from one season to another: in Europe, the water coming from thaws is stored in spring and summer and used during winter. One of the particularities of hydraulic is that the “fuel” is variable along the year, and the available power varies in the same way. Moreover, the amount of energy generated, depending on pluviometry, varies from year to year. In 2005, for example in France, the hydroelectricity production was smaller by a few percent compared to previous years due to a smallest pluviometry.

2. Presentation

There are 3 types of hydraulic plants:

Run-of-river: when the flow of a river does not vary very much during the year, with no difference in altitude, like for rivers in plains, there is no reservoir in front of the dam. The water that will be turbinated is running in a lateral canal.

Reservoir installation: for rivers that have variable flow along the year, the hydraulic potential is obtained with storage of upstream water when it is heavy. It’s often the case in the mountain.

Pumped storage: during off-peak periods, when there is too much electricity production compared to the demand, the water in a low basin is pumped to a high basin, to make a reserve which will be turbinated during peak periods. This is one of the only and easiest ways to store large amounts of energy for electricity production. The other one, compressed air storage, is very scarcely used. There is such a unit in Germany, for example.

By convention, the boundary separating large-size and small-size sectors is a purely administrative limit, fixed by European Commission. This limit has been fixed to 10 MW. Nevertheless, some countries use a different convention to differentiate between large and small-size hydraulic installations: this threshold is fixed to 12 MW in France for example (40 MW in China).

Characteristics, advantages and disadvantages, economic data of large-size and small-size hydraulics are very different.

Small-size hydraulic plants produce electricity at a more expensive cost than large-size ones. However, this electricity can be used locally which is ideal for the electrification of isolated sites. They can also eventually contribute to national electric power production when necessary. In Europe, the leading countries in terms of small-size installed capacities are respectively Italy, France, Germany and Sweden. These four countries alone represent 8,752 MW, i.e. 82 % of total European Union capacity.

It is because of hydroelectricity production (large-size and small-size) that France is the first producer of renewable energies in Europe. Installed capacity figures have evolved very little

over the last few years because, despite the existence of a real potential, any new project clashes almost systematically with local opposition that heavily slows down the sector's dynamism. Nonetheless, overhaul or renovation operations for already existing sites could create activity since nearly 70% of today's installations are more than 40 years old in Europe. The electricity yield of a hydraulic dam is very high, and can approach 90%.

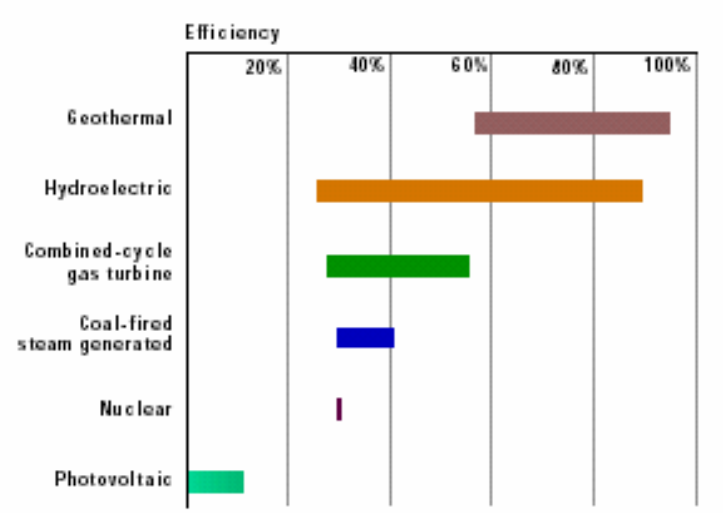

Figure 2 Comparing efficiencies of electricity generation, hydropower a key to prosperity in the growing world

The technology is mature (about hundred years of experience), and few spectacular progresses of costs or performance are expected. But improvements are possible concerning an increase of new installed capacities and availability, rehabilitation or renovation of actual plants (automation), environmental protection, and using of new materials.

3. European situation and trend

Hydraulic electricity production is used to balance supply and consumption. The electricity production is optimized for power and not quantity. The produced kWh is of high quality. Hydraulic energy is often used to store electricity. For example, in France, the installed capacity is about 27 GW (22 % of all electric plants) but the hydraulic production represents only 11.4% of total electric production in 2003.

Countries	Production 2003 (TWh)	Share of electricity production	Installed capacities (MW)
France	64,8	11,4 %	27 350
Sweden	53	39 %	17 230
Italy	44,2	15,1 %	22 160
Spain	43,8	16,8 %	16 995
Austria	35,6	57,8 %	12 220
Germany	23,6	3,9 %	10 380
Portugal	16	35,5%	4 745
Finland	9,4	11,4 %	3 230
United Kingdom	7,3	1,8 %	4 465
Greece	5,32	9,1 %	-
Slovakia	3,7	57,4 %	-
Poland	3,3	202 %	-
Slovenia	3,1	22,5 %	-
Leetonia	2,3	58,9 %	-
Czech Republic	1,82	2,2 %	-
Belgium	1,3	1,6 %	-
Ireland	1	4,5 %	-
Lithuania	1	5,4 %	-
Luxembourg	0,9	21,9 %	-
Hungry	0,17	0,5 %	-
Netherlands	0,07	0,1 %	-
Denmark	0,04	0,05 %	-
Estonia	0,005	0,05 %	-
Total	**324,7**	**13%**	**124 800**

Hydraulic power in European Union, Eurobserv'Er

Future developments in Europe will be in East countries, because several potential sites exist. However, little evolution is expected between before 2010.

The first objective of the European Commission's White Paper, set for 2003, was not reached (12,500 MW of new capacities production required). The sector's growth rate remained too weak for that. The economical and technical potential of large dams is already used, or unavailable because of environmental constraints.

There are large small-size hydraulic resources in the European Union. The estimated additional potential capacity of nearly 6,000 MW and only about 65% of this potential is developed. An increase of 4,500 MW for small-size plants is realist, with a favorable legislation. Concerning 2010 objectives, European small-size hydraulic capacity should be around 12,000 MW if the average annual growth rate of the last four years goes on.

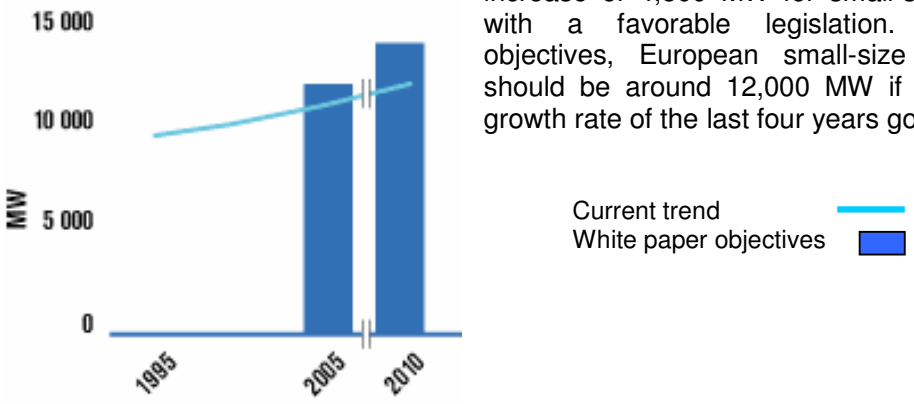

Figure 3 Small-size hydraulic current trend and White Paper objectives (in MW), Eurobserv'ER

Nevertheless, this figure is going to be below the target of the European Commission's White Paper. It should be underlined that this figure does not take into account the new member countries integrated on May 1st 2004, which means that a lot can be done in this area.

The total capacity in service of small-size dams, at the end of 2003, for the 15 members, was estimated at 10,734 MW and a lot of small plants are out-of-service, because of a lack of incentive for costs of maintenance. However, their repair needs only little investments, especially for isolated and rural installations. Nevertheless, European countries are leaders on the worldwide small-size hydraulic market.

Concerning large-size hydraulic, an increase of 10% of installed power for large dams is probable until 2010, with some ecological efforts.

4. Economy

This source of energy is characterized by large investments, but operating costs are very low, because the fuel is free, and maintenance reduced. Investments costs are very much depending on the characteristics of the dams (civil engineering), and additional expenditures concerning environmental and social problems. So, it is difficult to give normative price.

In France, the global average cost per kW is between 1 500€ and 3 000€. In spite of heavy investments, when those are paid off, hydraulic plants are very profitable in the long term run, because they have a long useful life. For the small-size hydraulic, a cost of 1250€/kW is pointed out by Eurostaf.

Operation and maintenance costs for hydro-electricity plants are considerably lower than for thermal electricity generating plants. There are few unscheduled breakdowns because their mechanical design is relatively simple, and no heat is generated during operations.

Economical and quickly started, this energy is greatly used during peaks, and permits to avoid expensive start of additional thermal plants and thus to save nuclear or fossil fuels. In terms of employment, European hydraulic industry represents about 10,000 jobs, for a turnover of 400 millions of euros (Eurobserv'Er).

5. Environment

Large-size hydraulic dams induce changes in natural surroundings, and usually, a large area of land has to be flooded.

Rivers usually experience seasonal flooding that flush out river backwaters and deposit silt on river banks. Dams prevent those seasonal floods and allow silt and vegetation to clog up river backwaters. These cause changes to the environments of many plants and animals and may cause a reduction in their populations.

But when precautions are taken, notably by protecting areas of spawning for fishes, or by conserving enough water in the flow, to permit to fishes going back in the river, there is practically no impact.

Hydroelectricity is a renewable energy source that does not produce greenhouse gases, and thus, does not emit CO_2 during operation. However, when the reservoir is on a large area of vegetation, methane is emitted during its decomposition.

A plant of 1MW producing 5GWh avoids each year the emission of about 5,000 tons of CO_2, compared to a thermal plant. In Europe, emission of about 60 Mtons of CO_2 is thus avoided.

Dam failures are also a main risk for the environment and human life. Some of them have made more than 1000 victims but most of them have not taken any human life. On the four failures in Europe since 1980, three of them were not deadly.

In France, this type of accident killed 540 peoples. But there has been heavy researches and improvement of security since the last important sinister in 1959 (423 victims at Malpasset) and this has improved the situation quite a lot.

6. Conclusion

Hydroelectricity is the best mean to produce electricity when a country has the possibility to do it. This is why it has been extensively developed in Europe in the past. In France, for example, 56% of the electricity was produced from hydraulic in 1960. This was even more before. Small hydraulic should be push forwards in Europe. The main problem to do that is the social acceptance of the energy resource which in fact has only very little impact on the environment.

7. References

Eurostaf march 2003
Eurobserv'ER
www.europa.fr
www.prim.net, main risk prevention for France
http://sfp.in2p3.fr/Debat/debat_energie/websfp/Hydraulique.htm, written by P.Bacher and B.Tardieu