SMALL HYDROPOWER SCHEMES AS AN IMPORTANTANT RENEWABLE ENERGY SOURCE

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Abstract

Generally speaking the countries policy is devoted to assure additional generating energy from renewable, in particular with hydropower schemes, which can contribute with a cheap source, as well as it can encourage internationally competitive small industries across a wide range of new energy source options. The hydraulic power is one of the oldest energy sources of mankind.

Small hydro is one of the most valuable answers to the question of how to offer to isolated or rural communities the benefits of electrification. It can answer to the many of the more complex problems of energy supply. The importance of small hydroelectricity growth to fill the gap of decentralised production and for private and municipal activity production, for sale to the general grid of electricity delivery or alternatively to furnish energy to the industry or even to isolated zones. Small hydropower, with its multiple advantages as low-cost and reliable form of energy, is in the forefront of many countries to achieve energy self-sufficiency.

1- INTRODUCTION

In some countries the energetic situation is still characterised by a strong dependence of external energy. In order to fill the gap of the primary energy need that is most imported, it is required another type of energy production (e.g. thermal or nuclear), however, much more polluted sources. Generally speaking, the policy in most of countries is devoted to assure additional generating energy from renewable, according to environmental constrains. Hydropower schemes can contribute with a cheap source, as well as to encourage the development of small industries across a wide range of new technologies.

The energy of flowing water is the most readily available, renewable and clean source of electricity. The hydraulic power is one of the oldest energy forms of mankind, namely used for irrigation and industry. Nowadays, small hydro is one of the most valuable answers to the question of how to offer to isolated rural communities the benefits of electrification and of progress, as well as to improve the quality of life.

Undertakings with multiple proposes, in particular water drink and irrigation systems take the advantage to install small or micro hydro schemes in existing local difference topographic levels or using a difference piezometric head along a pipe. These systems must be able to response to some operating constrains, such as fluid looping or closed circuit (e.g. by using reverse pump-turbine).

2- SUSTAINABLE MANAGEMENT AND WATER USES

The utilisation of renewable energies based on new technologies of which there are important factors to the developing of research works, such as turbine performance, efficiency of the system, control automation and computer codes for simulation different alternatives enables obtaining unconventional environmental solutions. Small hydropower systems allow achieving self-sufficiency by using the best

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as possible the scarce natural resource that is the water, as a decentralised and low-cost of energy production, since they are in the forefront of many developing countries**.**

In Europe the development of small hydroelectricity grows up since the seventy decade, essentially, caused by the world energy crisis, and the concerns of negative environmental impacts associated to the energy production. The small hydropower can fill the gap of decentralised production, for instance the private or municipal activity, in order to sale the energy to national electric grid or for own supply of small industries, rural or isolated zones, improving the regional development, with local important significance.

Water resources can be used in different ways to serve the society, taking into consideration all demands arising from different social and economic sector-users. Meanwhile the exploitation and utilisation of water resources aims to obtain the maximum benefit, and should be controlled in order to reduce natural hazards and significant environmental impacts.

The small hydropower schemes can be associated with different water uses:

Power generation and water supply - Water conveyance circuits used to feed water supply systems of a town through a pressure pipe, from a reservoir to a treatment plant are, normally, equipped by valve systems (e.g. pressure reducing valves – PRV) in order to dissipate excess energy in localised pipe sections. In fact, a turbine can substitute this dissipater system (Figure 1). When hydropower stations are installed in drinking systems will work under pressure conditions, imposing special regulation and control systems due to variability of water daily demand.

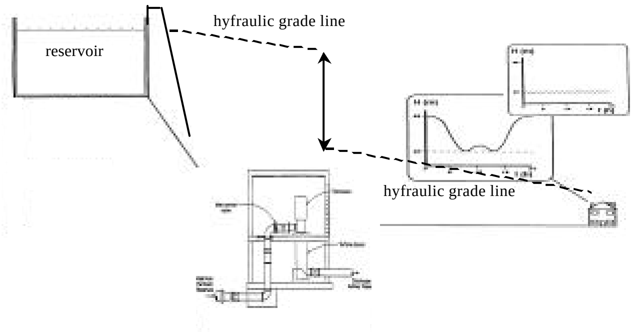

Fig. 1 – A scheme of a micro turbine installed in a water supply system

Power generation and irrigation – General speaking there are two types of facilities: one within the irrigation canal and another in a lateral by-pass canal (Figure 2), which feeds the penstock, in order to take the advantage of a local significant difference topographic level created by a dam or a weir. In several irrigation schemes there is the opportunity to introduce a small powerplant on the canal and to convert, permanently or seasonally, the excess head into energy by the following way:

- whenever a dam imposes an excess head relatively to the downstream delivery flow, a turbine scheme can be envisaged in order to replace, totally or partially, a dissipation structure;
- along an irrigation canal system, significant difference topographic level can be used and a diversion scheme can be implemented out of irrigation period.

Fig. 2 – Power generation in an irrigation scheme

Power generation and flood prevention **-** Dams can be used to prevent floods creating reservoirs that should be emptied ahead of the rainy season, although allocating a certain volume in the reservoir, especially for power generation. An integrated reservoir operation management tends, nowadays, to reduce the energy loss to a minimum, benefiting sometimes the waterpower.

Power generation and fisheries or tourism **-** Damming a river impedes fish migration and the passage between downstream to upstream sides requiring the design of a fish passage. However the reservoir, although small would create a special spot for recreational opportunities improving the landscape, and breeding conditions for aqua-culture.

Power generation and environment protection – Most hydropower projects have dams, therefore the river habitat is often replaced by a lake habitat. The exploitation of a small hydropower has low effect on the environment, in particular in the water quality, comparing with others power systems. Thus, the hydropower is considerable, in general way, as a non-polluting energy source comparing with traditional energy production systems based on fossil fuels or radioactive components.

3- CLEANER ENERGY SYSTEM

Hydropower is the most important energy source in what concerns no carbon dioxide, sulphur dioxide, nitrous oxides or any other type of air emissions and no solid or liquid wastes production. The introduction of innovative solutions coupled to renewable energy technologies should contribute to a substantial global reduction in emission of CO_2 and other gases, which are responsible for greenhouse effects.

A cleaner energy system is, normally, associated to renewable concept that includes the main following remarks: inexhaustible energetic sources, in spite of being of limited or conditioned utilisation; low polluted energy or with small environmental effects; relevant component of a sustainable development.

The hydroelectric power plant utilises a natural or artificial fall of a river and enhances the main advantages comparing with other electricity sources, namely saving consumption of fossil, fuel, or firewood, being self-sufficient without the need of imported components. Small hydropower schemes do not contribute for greenhouse effects or atmospheric pollution and for resettlement, since happen with large dams, offering a decentralised electrification at low running cost and long life.

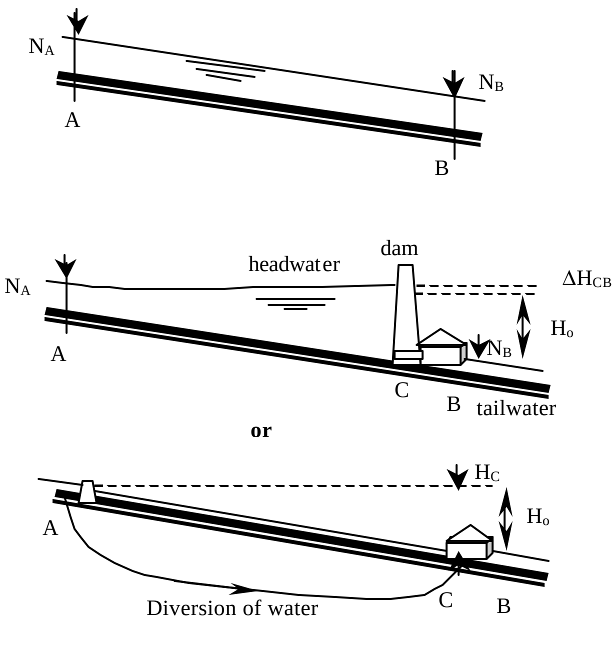

Fig. 3 – Different types of hydropower schemes

The net head (H_o) of a small hydropower plant (Figure 3) can be created in quite number of ways, being the most known the following two types: building a dam across a stream in order to increase the water level just above the plant; or diverting part of the stream, with a minimum of headloss, to just above the plant.
The hydroelectricity production is an energy conversion process in which the water is an efficient vehicle of transmission and transformation of the gravity potential flow energy in mechanical and electric energy. In this way, the available potential energy or gross head (H_g) will be converted through the main following components of the hydropower system (Figure 4):

- Reservoir: constitute a storage form of the available potential energy;
- Conveyance system that includes the intake, conveyance circuit (i.e. canal, penstock, galleries and tailrace or outlet) where part of the available energy is converted into kinetic energy, being part transformed into reversible flow work capacity (pressure head), and another part dissipated in heat (by fluid viscosity), yielding in the net or useful head (H_o).
- Hydraulic turbine: where the net head is totally converted into kinetic energy of the flow that by impact on the runner (for impulse turbines), allows converting it into the rotor speed of the turbomachine. The turbine discharge variation induces effects on kinetic energy flow variation and on pressure work in the turbine runner (for reaction turbines).
- Generator rotor: the mechanical energy transmitted to the shaft maintain the speed of the rotor producing electric energy according to electromagnetic laws;
- Linkage line to the grid: the electric energy is driven and transformed in order to connect to the grid that it will be transported to long distances and for posterior users' distribution.

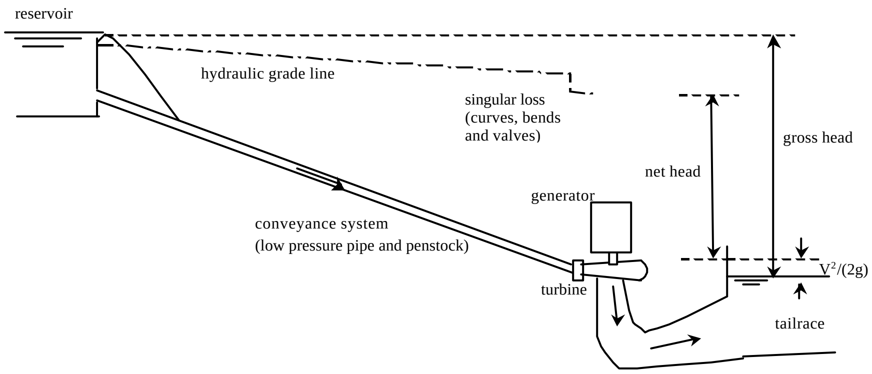

Fig. 4 – Components of a hydropower scheme

The basic hydropower principle is based on the conversion of a large part of the gross head, H_g (m), (i.e. net head H_o (m)) into mechanical and electrical energy:

$$H_o = H_g - \Delta H_{AB} \tag{1}$$

being head losses along the total conversion system expressed by ΔH_{AB} (m).

The hydraulic power Po (kW) and the corresponding energy Eo (kWh) over an interval time Δt (h) will be respectively:

$$\begin{aligned} P_o &= \rho g\, Q\, H_o \\ E_o &= \rho g\, Q\, H_o \Delta t \end{aligned} \tag{2}$$

where Q (m^3/s) is the discharge diverted to the powerplant.

The final power (P_F) delivered to the network is smaller than the available hydraulic power (P_o):

$$P_F = \eta \, P_o \tag{3}$$

where h is the global efficiency, resulted of the multiplication of partial efficiencies from the successive transport and conversion phases ($h < 1$) (Figure 5).

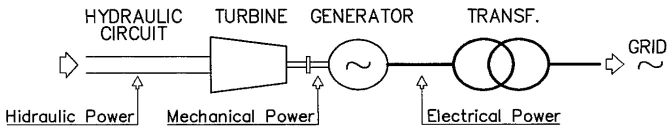

Fig. 5 - Power conversion scheme

4- ECONOMIC AND EFFICIENT ENERGY

Hydropower is more reliable and efficient and less expensive energy source than geothermal, biomass, wind and solar energy. Research and technological development in the field of the environment, energy and sustainable management of ecosystem resources are essentials for the implementation of a competitive global policy. These fields must go hand in hand with economic and industrial developments that respect the environment and the quality of life.
Small hydropower plants have proved in several countries and under some conditions to be a good capital investment, many times chosen by developing or developed countries, through turbine performance improvement that has been more and more competitiveness in the power world market. The energy source can provide Europe and other countries with a reliable, efficient, safe and economic source for more and more system effectiveness for decentralised industries.
The improvement of turbine performance is visible through the turbine efficiency for a large spectrum of discharge and head (Figure 6).

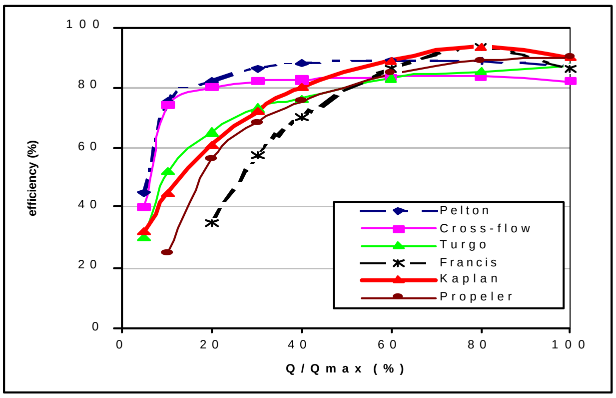

Fig. 6 – Turbine efficiencies

5- RESEARCH AND TECHNOLOGY

Although research and technological development in the field of environment and energy are closely related, they remain distinct areas. The research ought to develop the necessary scientific knowledge and practical tools base on environmental monitoring implementation systems for better evaluation of unconventional technical solutions, improving the efficiency of new and renewable energy sources, in particular the small hydropower. The elaboration of alternative scenarios on design and exploitation in terms of economy/environment/energy factors and their owns interactions must carry out within each solution, in order to allow choosing the best one.

Although the hydraulic circuit can be integrated in other hydraulic components for multiple purposes, the hydraulic structures associated to hydropower implementation tend to be less complex and the turbo-generators standardised.

The hydraulic engineering intervention has a major contribution in these types of undertakings, namely in the planning, conception, and study development, design, and building and exploitation stages of a project that involves multidisciplinary teams with technicians and experts in several domains. In small hydropower plants the development of automation and remote control systems (i.e. allowing abandoned exploitation) and the standardisation of the equipment (e.g. turbines and generators) based on research and technology development, allow renewable schemes adopting advanced techniques and with commercial ripeness. The present concept of small-scale hydropower is neither the miniature of large hydro nor the simple repetition of old techniques, but advanced techniques appropriated to each case, independently of each country (e.g. developed or developing country).

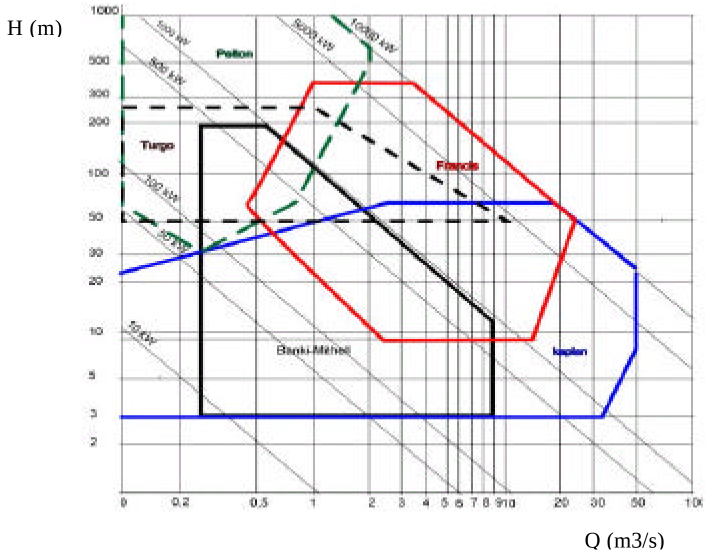

Fig. 7 – Range of turbine application

The use of micro-turbines will depend on the type of circuit that can be standing out, fundamentally, by three characteristic types: a totally pressurised circuit; a pressurised circuit but with intermediate reservoirs (e.g. treatment plants or ground reservoirs); a free-surface flow system (e.g. irrigation canals).

Pressurised systems require, normally, reaction turbines (e.g. Francis and Kaplan or propeller) or reverse pump-turbines. These types of turbines present the main advantages by maintaining the flow under pressure and avoiding, therefore, dangerous contamination problems, in case of drinking water systems.

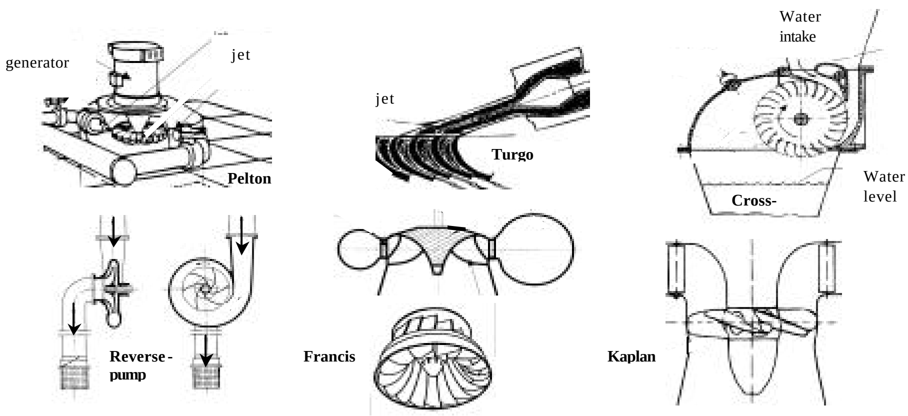

Fig. – 8 – Turbine set of impulse, reaction and reverse-pump types

In case of high difference piezometric heads or whenever head allow impulse turbines will be adopted (e.g. Pelton, turgo and cross-flow), which can substitute loss chambers, nevertheless imposing a free surface tailrace. This type of turbines is not recommended for drinking water systems because water quality can be affected, unless should it located at upstream of a treatment plant.
In free-surface flow systems (e.g. irrigation canals) can be used reaction turbines for low or medium heads (e.g. high specific speed turbines – Francis, Kaplan and bulb) installed in open flume canals.
Large ranges of turbine set - such as impulse, reaction turbines and reverse pump-turbines - can be used depending on the system characteristics (Figure 7 and 8).
Therefore, the choice of a hydro generation site must be rigorous, depending on different solutions to be adopted for the water conveyance system and powerhouse, mainly conditioned by head and flow requirements, according to feasibility technical-economic analysis.

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