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TYPIFICATION OF SHPPS DEVELOPMENT

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Nowadays the development of renewable energies has become a necessity. The increase in electricity demands combined with international agreements to reduce greenhouse gas emissions to limit fossil energy use and ensure security of supply by reducing the dependence on the importation of fossil fuels are strong arguments for the development of renewable energies. Hydropower is the foremost electricity-producing renewable energy technology in terms of installed capacity and energy yield, both in Europe and the world.

Developing a small hydropower (SHP) site is not a simple task since small hydropower is not simply a reduced version of large hydro plant. Thus it is essential to develop and produce equipments specific to small power plants so as to assure the fundamental exigencies of simplicity, high energy efficiency, maximum reliability and easy maintenance.

Currently, most efforts concerning civil engineering aim at standardizing design and technology, in order to reach an optimal development of SHP plants (SHPP) and integration with the local environment while minimizing costs. Besides the works of civil engineering, the industry of the small hydropower associates mechanical and electrical high technologies combined with highly developed monitoring and surveillance processes.

The paper describes the criterion of micro hydropower development typification, the classification of micro hydropower plants depending of available head, as well as the possibilities of capitalization and consumption of the produced energy.

Keywords: micro hydropower, micropotential, hydro scheme, small HPP, powerhouse, turbines.

1. Introduction

Nowadays the development of renewable energies has become a necessity since the climate change due to CO_2 emissions has been defined as the major environmental challenge to be faced by the International Community. The community targets are clearly stated at The Rio conference in 1992, The Kyoto protocol in 1997, and into the European White Paper "Energy for the future:

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renewable sources of energy" and finally the "Directive/77/EC of the European Parliament and of the European Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market", which gives a clear signal that greater use of renewable energy is necessary to reduce environmental impacts, ensure security of supply and create a sustainable energy system.

Small hydropower (SHP) has a key role to play in the development of Europe's renewable energy resources, particularly in view of the new enlarged European Union and its increasing electricity demand, and also, interest is increasing in developing SHP because large hydro sites are generally already being exploited in many European countries. Small hydropower is a much more concentrated energy resource than other renewable, it is predictable, non-varying and has a higher capacity factor and long life.

The main advantages of SHP are: it is a clean and renewable energy source, contributes towards sustainable development, and respects the environment (no green house gases emissions); it ensure a minimum flow downstream (the reserved flow) that guarantees downstream life of aquatic organisms; SHP mobilizes financial resources and contributes to the economic development of small scattered populations, ensuring autonomous and reliable energy for the long term; SHP plants create local jobs for the monitoring of the running phase of the plant; by being located close to the consumers, transmission losses can be reduced and the electricity supply lines are eased; assist in maintaining river basins by allowing the recovery of wastes that flow in the river stream; SHP plants, if well-equipped, with fish ladders are not an obstacle for migratory fish. SHP should be distinguished from the usual hydropower because a small power plant can not be realized just by a simple geometric reduction of a big one. Such a process would lead to an excessive damage of the performances in case of a non-controlled simplification of the turbine geometry or to an expensive, complex and of a delicate exploitation construction. Until now, SHP has not developed itself as much as the other RES. SHP development is slowed down by numerous institutional barriers and by the wrong idea that it is a mature technology and that SHP plants injure water streams regarding ecology and leisure interests.

The purpose of this paper is to presents the possibilities of typification of SHP plants (SHPP).

2. SHP plants typification

The objective of a hydro power scheme is to convert the potential energy of water, flowing in a stream with a certain fall (*head*), into electric energy. The power of the scheme is proportional to the flow (m^3/s) and to the head (m).

2.1. Criterions of SHPP schemes typification

The criteria of SHP plants schemes typification can be made on various points of views:

⇨ considering the location of the micropotential to be used: ◆ upstream of the existing developments, where hydroenergetic potential unused still exists; ◆ on the downstream area of the rivers, after the existing developments; ◆ by using the unexploited flow and heads within the existing hydroenergetic developments; ◆ into the existing hydrotechnic works (water supply, irrigation, flood prevention, fisheries or tourism);

⇨ considering the head: high head schemes; medium head schemes; low head schemes;

⇨ regarding the types of turbine employed: schemes which use Pelton turbines; schemes which use Francis turbines; schemes which use Kaplan turbines; schemes which use bulb turbines; schemes which use Banki turbines; schemes which use EOS turbines;

⇨ considering the manner in which the produced electric energy is consumed: the energy can be consumed in the production place, or it can be supplied in the local distribution network.

2.2. Types of development schemes

The gross head of a river sector is given by:

$$H_{br1\text{-}2} = z_1 - z_2 + \frac{\alpha v_1^2 - \alpha v_2^2}{2g} \tag{1}$$

with z_1, z_2 represents the absolute elevation of the sector ends, and v_1, v_2 the average velocities in the given sections.

The hydropower developments gather the flow and heads on short river sectors, assuring and increasing in the main time the energy production.

The increased head of a small hydropower plant can be created in quite number of ways, being the most known the following ones:

⇨ the local rise of water level: it is succeeded by building a dam across a stream which increase the water level and creates a larger flow section upstream; it is usually used in river valleys areas; the kinetic terms are very important

⇨ diverting part of the stream, by a channel with a smaller slope and with a minimum of headlosses;

⇨ the combined solution, which imply the local rise of water level by a dam, and then the water diversion; the power house can be aerian or underground; they are typically for the upper river courses; the kinetic terms can be ignored.

The hydromechanics and electrical equipments are very important in electing the type of scheme to be realized. The hydraulic turbines, the electric generators, the vanes, the annexes, are plant specific, while the electrical connection stations, the command chambers, the electric transformers are not.

The typical schemes are particularized according to the relief characteristics, river slope, geological features, land use in the area, the turbine type used and so on. A typical development for a SHP plant scheme, which involves a dam, is presented in figure 1.

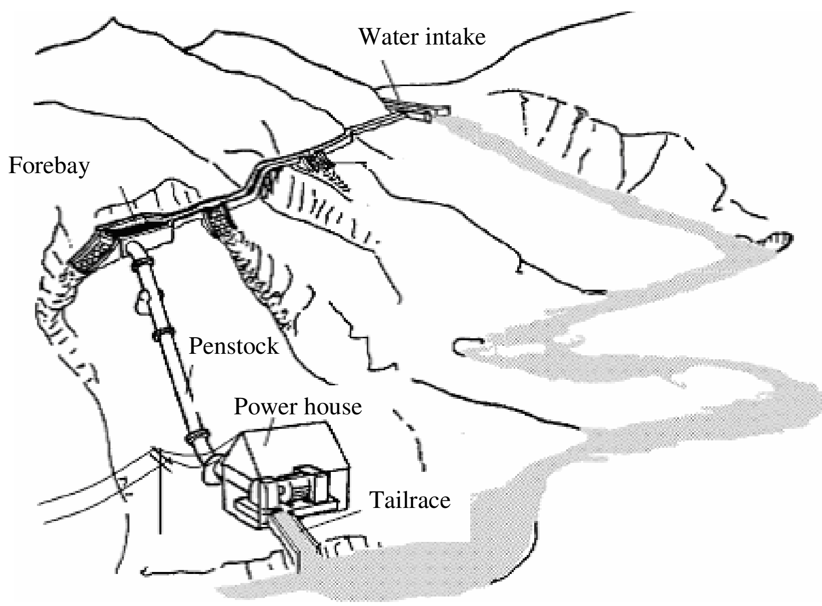

Fig. 1. Typical SHP plant scheme.

2.3. SHPP classification according to the head

As mentioned before, the SHP plants can be classified as follow: ◆ high head schemes, with $H_{br} \geq 100\text{m}$, usually used in mountain area (upper courses of rivers); ◆ medium head schemes, $30\text{m} \leq H_{br} \leq 100\text{m}$, usually used in mountain and hills areas (medium river courses); ◆ low head schemes, $2\text{m} \leq H_{br} \leq 30\text{m}$, typically used in river valleys (lower river courses).

2.4. Turbines used in SHPP

A large spectrum of turbines can be employed, according to the available flow and heads: Pelton, Francis, Kaplan, Bulb, Banki, EOS, Turgo. The choice of the right turbine for a particular application must relay on the specific speed of the turbine, n_s, given by:

$$n_s = \frac{n}{H_{br}}\sqrt{\frac{1{,}36P}{\sqrt{H_{br}}}}\ , \tag{2}$$

and the gross head, H_{br} (see table 1).

Table 1

Range of specific speed and heads

Turbine type		Specific speed n_s	Gross head H_{br} (m)
Pelton	slow normal rapid	1 - 10 11 - 25 26 - 60	> 300
Francis	slow normal rapid	60 -150 151 -250 251 -350	50-625
Kaplan	slow normal rapid	300 - 600 601 - 800 801 -1200	10-90
Bulb	slow normal rapid	500 - 900 901 -1400 1401 -2000	< 16,5

2.5. Energy consumption

The energy produces can be used directly to the production place, instead of using the electricity from the local grid. Another option is to supply the electricity into the local grid. Economically, the most feasible solution is to consume as much at possible the production location, and to supply only the surplus into the local electric grid.

Hydroelectric power, as it has in the past, will continue to be a significant player in the electric power industry. However, there remain many challenges ahead as environmental and legal issues are played out.

3. Specific features of SHPP

The hydropower schemes of SHPP have a specific construction, different from the traditional hydropower developments. SHPP have to be simple, robust and in the same time to assure the energy production specified.

The hydropower schemes of a SHPP usually contain: the retention sill; the lateral water intake; the desilting basin and the forebay; the conveyance structure which carries the design flow from the water intake to the power house; the power house which houses the turbine, generator and controller units; the tailrace which allows the water to flow back to the stream after it has passed through the turbine.

The water intake must be able to divert the required amount of water to the power house, with the minimum possible headlosses. The intake serves as a transition between a stream that can vary from a trickle to a raging torrent, and a controlled flow of water both in quality and quantity. Its design, based on geological, hydraulic, structural and economic considerations, requires special care to avoid unnecessary maintenance and operational problems that cannot be easily remedied and would have to be tolerated for the life of the project. A very important step is to properly choose the intake type for the proposed scheme. The location of the intake depends on a number of factors, such as submergence, geotechnical conditions, environmental considerations where necessary. The orientation of the intake entrance to the flow is a crucial factor in minimizing debris accumulation on the trashrack, a source of future maintenance problems and plant stoppages. The intake should not be located in an area of still water, far from the spillway, because the eddy currents common in such waters will entrain and accumulate trash at the entrance. The water intake should be equipped with a trashrack to minimise the amount of debris and sediment carried by the incoming water, a settling basin where the flow velocity is reduced, a sluicing system to flush the deposited silt, sand, gravel and pebbles with a minimum of water loss, and a spillway to divert the excess water.

The penstock pipe transports water under pressure from the forebay tank to the turbine, where the potential energy of the water is converted into kinetic energy in order to rotate the turbine. This task may not appear as difficult, considering the familiarity of water pipes; however, deciding the most economical arrangement for a penstock is not so simple. Penstocks can be installed over or under the ground, depending on factors such as the nature of the ground itself, the penstock material, the ambient temperatures and the environmental requirements. The characteristics of a penstock are materials (selected according to the ground conditions, accessibility, weight, jointing system and cost), diameter (selected to reduce frictional losses within the penstock to an acceptable level), wall thickness (selected to resist the maximum internal hydraulic pressure, including transient surge pressure that will occur) and type of joint (if necessary).

In a small hydropower scheme the role of the powerhouse is to protect from the weather hardships the electromechanical equipment that convert the potential energy of water into electricity. The number, type and power of the turbo-generators, their configuration, the scheme head and the geomorphology of the site control the shape and size of the building.

The compensation basin assures the uninterrupted function of the plant during the low flow periods, when the river flow is less then the needed one to the turbines. They also control the flow after passing through the turbine, according to the local necessities. Usually, their capacity is rather small, and the water level varies to few meters at most, depending on the ground conditions.

After passing through the turbine the water returns to the river trough a short canal called a tailrace. Impulse turbines can have relatively high exit velocities, so the tailrace should be designed to ensure that the powerhouse would not be undermined. Protection with rock riprap or concrete aprons should be provided between the powerhouse and the stream. The design should also ensure that during relatively high flows the water in the tailrace does not rise so far that it interferes with the turbine runner. With a reaction turbine the level of the water in the tailrace influences the operation of the turbine and more specifically the onset of cavitation. This level also determines the available net head and in low head systems may have a decisive influence on the economic results.

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