

If you don't know where to go, at least know where you come from¹

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Introduction

Two of the authors of this paper have attended, together, all the Hidroenergia conferences since the first organised in 1989 thanks to the enthusiastic and far-sighted work of Celso Pence; now they try to share their experience and to draw some remarks about the evolution of the SH sector, through an overview of the topics and an analysis of the most interesting ones - arbitrarily selected by the authors themselves!

Picture 1 – Celso Pence

1 The topics

Taking a look at the conference proceedings, one of the first remarks is that some issues are always present, important and (often) debated.

The following list shows some examples of these “evergreen” topics.

- Cost reduction: achieved by standardization of components and automation of plant operation.
- Environmental impact and reserved flow: a debate more ancient than one may think.
- Exploitation of low heads: still a technical - if not technological - challenge.
- Support measures: incentives, tariffs, etc.
- Success stories and lesson learning: two faces of the same medal, that is learning from the past, as the title of the paper itself suggests!

Of course, while the topics are still there, their contents have evolved in these years: for instance new technologies (both electromechanical and civil) have been developed for developing *low head sites*, a wide range of measures have been devised to reduce the *environmental impact* of HPPs, a lot of formulae have been proposed to determine the *reserved* (also called *ecological*) *flow* to be released downstream of a river diversion, and so on.

2 The evolution

The evolution of the SHP sector in the last two decades can be roughly summarized as follows.

The occurrence of challenging conditions

- difficult and unstable economic context
- competition with other RES (mainly PV and wind)

¹ Paper and presentation dedicated to **Celso Penche**, first General Secretary of ESHA and the organiser of the first HIDROENERGIA meeting (Madrid 1989)

- competition with other water users (navigation, irrigation, drinking or waste water systems)
- unfavourable administrative and authorization procedures
- strict environmental laws and regulations
- most favourable sites (mainly high heads) already developed

has called for

- cost reduction
- exploitation of every water drop
- development of least favourable sites (low heads)
- action and lobbying on the regulatory and administrative side

and this has translated into

- projects and programmes (at national and community level) for HP support and promotion
- rehabilitation and refurbishment (which can provide the same production increase as the realization of a new plant)
- further R&D (within an already mature technology) which has in turn led to
 - cost reduction through standardization and automation
 - development of low and very low head sites (always a technical challenge)
 - minimization of environmental impact (visual, acoustic and so on)
 - plants on reserved flow (whose viability usually depends, more than for other types of plants, on the existence of authorization and financial facilitations)
 - multipurpose schemes (which can make shorter and easier - or less difficult - the way to water rights, by aggregating different water uses)
 - grid friendly solutions (e.g. smart grids and pumped storage, whose contribution to grid stability becomes increasingly important with the development of the concurrent and more “fluctuating” RES, mainly PV but also wind)

3 Interesting examples

A few selected papers are described in the following, presenting interesting combinations of the abovementioned “hottest” topics, and at the same time showing the evolution of the SH sector and of its many (and entwined) branches during the years.

3.1 Cost reduction

This is not only an “evergreen” theme, but also a very wide one: several issues, connected with each other and reflected in the papers presented throughout the years and the conferences, converge in it, because every project in the real world must deal with the economic aspect, in the end.

First of all, it's worth remarking that *small hydro means small business*, i.e. small hydropower plants have much lower incomes, as well as environmental impacts, compared to large ones and in particular to those with large reservoirs; therefore they need (and “deserve”) to have also lower costs.

In particular the (warranted) efficiency of their electromechanical equipment must be comparable to that of large installations, while the cost must be much smaller. For this purpose, laboratory testing and R&D are necessary; this demand finds a response in the work of companies such as MHyLab, whose work covers a great variety of issues in the SH sector: an overview of the past Hidroenergia meetings reveals presentations on axial, diagonal and siphon turbines; high, low and medium heads; CAD and laboratory development, just to mention a few meaningful topics.

The cost reduction issue was already treated in the first edition of Hidroenergia (Madrid 1989) by the paper “*Cost reduction of equipment through standardisation and manufacturing automation*”, which focused in particular on the normalization (by means of curves and charts based on specific speed) of the hydraulic and mechanical design and on the standardization (without compromising the quality) of the supply of specific elements such as generators, HPUs, etc; in the end, anyway, the paper reminds that a good design and realization implies more RES production, with clear advantages from the economic as well as from the environmental point of view.

In the second edition (Nice 1991) the paper “*An innovative design of low head small hydroelectric units for low cost decentralised production*” illustrated the development of a low cost technology,

based on serial production and on the use of plastic materials, to develop low head sites in a cheap (but still acceptably efficient) way. In particular the turbine concept is a high pressure recovery semi-Kaplan with a fixed vane ring assembly and manually adjustable runner blades; the combination of several design features, made possible by R&D, offers relatively good efficiencies (globally 70% for heads around 2 m, and more for higher heads, thanks to the small head losses in the reinforced plastic waterways) and low costs compared to metallic waterways. Finally, by installing two or more parallel units, it's possible to deal with large flow rates and seasonal fluctuations.

The paper “*ESHA and the European ATLAS*”, presented at Hidroenergia 1993 in Munich, provides an interesting example of the many attempts at automating the preliminary site assessments (i.e. head and flow rate) in order to reduce their times and costs. In particular this EC Project (awarded to ESHA) aimed at creating an atlas of the European hydropower potential, through the development of flow duration curves (based on available precipitation, evapo-transpiration and soil data) for ungauged catchments, in order to enable people without hydrological expertise to evaluate the probable viability of a particular site, and consequently decide whether a detailed feasibility study is worth making or not. In the meantime, looking at the number of “Layman's guides” issued since 1989, could we wonder how judicious is that [the aforesaid] people without hydrological expertise may carry out a SH project

At Hidroenergia 1997, held in Dublin, the paper “*Petits aménagements hydroélectriques - Cahier des charges type: spécifications techniques propres aux équipements*”, that is “*Typical technical specifications for the equipments of small hydroelectric plants*”, witnesses the need to reduce supply costs in various ways, for instance by means of flexible contracts, leaving the suppliers free to choose the technical solutions that minimize the prices while providing the required quality level. Another suggestion to plant owners is to carefully choose the warranties and checking to ask for, as some of them have no practical importance (for instance the warranties that can't be checked with adequate precision or the checking with no real interest - such as the turbine efficiency for discharges much higher than the rated flow - or too difficult and costly to be measured - such as some measurements of discharge for low head turbines efficiency test) while all of them increase the final cost of supply.

Another contribution to cost reduction in an early planning stage (e.g. feasibility study) can be found in the paper “*Cost structure and cost optimisation of electromechanical components of hydropower plants*”, presented at Mulhouse in 2002, which shows how the complex task of optimising the costs of HPPs (in particular of the powerhouse and its electromechanical components) requires adequate knowledge and technological tools. The former requirement has implied literature research (and some contributions from manufacturers) on the cost structure of electromechanical equipment, while the latter has been fulfilled by a computer program implementing the Genetic Algorithm for the mathematical optimisation of the cost formulae derived from the previous phase of research; the result is a tool for selecting the appropriate type, number and layout of the powerhouse components, so the minimum cost solution can be identified and developed since the first steps of the design process.

Finally, coming to the recent years, the last Hidroenergia meeting, held in Lausanne in 2010, provided a great deal of contributions to the issue of cost reduction, so we can only briefly mention a few topics. On the side of components cost reduction, two meaningful instances provide, respectively, a review of the technology and applications of centrifugal pumps used as turbines, and of GRP pipes casing as an economic (and easy to install) alternative to steel casing; on the other side, that is the facilitation of the preliminary assessments, we found interesting contributions dealing with the EU project (coordinated by ESHA) STREAM MAP for presenting the current situation of the SH sector (creating a database - called HYDI - of energy, market and policy data) and evaluating the HP potential in Europe, and with the tools (GIS and computer models) for hydrological forecast and HP potential assessment.

These examples witness the constant development of the SH technology, always aiming at technical and technological solutions providing higher efficiency (which means more clean energy production) with minimum costs and impacts.

3.2 Environmental impact and reserved flow (*plus* low heads, multipurpose schemes, R&D, incentives)

First of all, the first rules have originated from local stakeholders' (green parties, fishermen and so on) demands, very little scientific but very incisive, which have been set into national laws, with little sci-

entific base and coherence; on the EC side, the environmental laws are generally framework directives (such as the WFD) very “general” and difficult to apply in practice due to the site specificities and the problems in defining general concepts such as “Good Ecological Status” and “Heavily Modified Water Body”. Our opinion is that the reserved flow is the “environmental fee” of HP, as it reduces to acceptable terms the only real impact of HP at local level. (Visual and acoustic impacts can be reduced as much as required - within sensible requirements, as it's not always the case - by using adequate technologies.)

A very interesting idea is to develop the obligation of reserved flow release into an opportunity of producing clean renewable energy; a great deal of plants exploiting the reserved flow are currently being designed and implemented, as witnessed by the paper “*Chievo small hydro plant - from the obligation of reserved flow to the opportunity of RES production*”, presented at Hidroenergia 2010 in Lausanne, which is connected to many other “hot” topics.

Actually the plant is designed across a ship lock (so it is, to a certain degree, a *multipurpose scheme*) and it exploits the reserved flow (60 m³/s) released at Chievo Dam, a movable weir (diverting water into the headrace channel of an existing HP plant) located on Adige River, just upstream of the city of Verona, in Northern Italy. The project is also an example of environmental (especially visual) impact reduction and of low heads (3,80 m) utilization, made possible (i.e. technically and economically feasible) by the latest *technological developments* (Straflomatrix™ technology, allowing for compact construction and minimum space occupation, as well as the possibility to lift the whole generating unit in case of flood or of possible ship passage) and by the existence of *incentives* for RES production.

Finally, as we mentioned the topic of technological developments, two recent innovations, concerning the electromechanical equipment, deserve a few words.

1. Very Low Head (VLH) turbines: specifically designed by mr. Jacques Fonkenell, a long experienced specialist in the field, for heads ranging from 1,4 to 3,2 m, they're also fish friendly. They've been illustrated first in the paper “*V.L.H. The Very Low Head Turbo-Generator for extremely low water falls*”, presented at the Hidroenergia conference held in Crieff (Scotland) in 2006, and then in other papers (presented by MJ2) dealing with testing and operating experiences, presented at Hidroenergia 2008 in Bled and at Hidroenergia 2010 in Lausanne.
2. Variable Speed Generators (VSG) with permanent magnets: they're a good option for low head SH applications, such as the ECOBulb technology, where they provide compact-size and high-efficiency solutions; the main limits of their application remains the costs, as usual.

These two innovations, on the turbine side and one on the generator side, have helped make viable the development of very low (and variable, which is as much important) head sites, allowing for the use of large and slow turbines (without draft tube) directly coupled to standard-size generators, thus avoiding the use of gear-boxes and the consequent operating problems (noise and maintenance) and costs.

3.3 Multipurpose schemes (*plus low heads*)

The issues of multipurpose schemes and low head sites development are dealt with in so many papers that it's not easy nor convenient to focus on any one in particular. We simply remark that even high head sites can be developed with multipurpose schemes, for instance some dams combine hydropower and water supply; in practice, anyway, the most common (and also promising, in terms of sites yet to be developed) combination is represented by hydropower on irrigation canals (which obviously have low heads, but whose flow rates can be quite high and also regularly monitored) but also on drinking water supply networks (which can also provide high heads, especially in mountainous zones, and flow rates ranging from a few l/s to some m³/s) and even wastewater treatment lines.

3.4 Refurbishment and lesson learning (*plus low heads*)

There are many examples which might be chosen, but they're all summarized by the “*Guide on how to refurbish a low head small hydroelectric plant*”, issued within SHAPES (Small Hydro Action for the Promotion of Efficient Solutions) project coordinated by ESHA and presented at Hidroenergia 2010 in Lausanne, where the general approach was illustrated with some case studies and lessons learnt.

In particular the main actions to be undertaken for refurbishments are described, following the factors which influence the Net Present Value of the investment, i.e. flow rate, net head, overall efficiency,

operating hours and O&M costs; the guide is completed by useful remarks and suggestions, as well as critical reviews of technical solutions, derived from the experience of the authors and contributors.

4 Conclusions

On the basis of what we've seen in these years, and reviewed through the conference proceedings, we deem that the present and future of (small) hydropower is summarized by the following issues.

- Rehabilitations and refurbishments: as HP is a mature technology, nowadays a lot of plants have been in operation for many decades, and some of them desperately need refurbishing.
- Low heads, especially on (irrigation) canals: high head sites are (have been) developed first.
- Multipurpose sites: always important, but even more so with the increasing competition for the use of water.
- Pumped storage and smart grids: they're important for grid stability, particularly now, with the development of other more "fluctuating" RESs (especially PV, but also wind) which are a source of instability.

Nomenclature

SHP = Small Hydro Power

HPP = Hydro Power Plant

RES = Renewable Energy Source

PV = Photovoltaic

R&D = Research and Development

O&M = Operation and Maintenance

CAD = Computer Aided Design

EC = European Community

ESHA = European Small Hydropower Association

WFD = Water Framework Directive

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