OPTIMIZATION OF HYDRO-POWER PLANTS: A FINANCIAL APPROACH IN THE GREEN CERTIFICATES FRAMEWORK

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Abstract

The paper regards the "financial efficiency" of the optimization of HPP, in other words to what extend it's worth improving the efficiency.
The convenience strongly depends on the energy price, but is also influenced by the public support scheme, based in Italy on the "green certificates".
Italian law grants green certificates not only to new plants, but also to powered and refurbished ones, supporting the plant upgrading.
The choice of the plant optimization project needs a cost-benefit analysis, comparing the further revenues, coming from the efficiency increase, to the costs of the tasks.
The paper highlights that the expected and real unit efficiency has a dramatic impact on the optimization of a hydro power plant, so it shouldn't remain just an act of faith.
A case study is presented.

Different meanings of efficiency

A successful optimization of an existing hydro power plant should get the best result under the following aspects.

- Technical efficiency
- Operational efficiency
- Financial efficiency

Of course, the main purpose is to improve the exploitation of the available hydraulic resource, increasing, where possible, the maximum flow rate, the effective head and the machinery efficiency.

But the operational efficiency isn't less important than the technical one, because it affects the plant reliability. The production is the result of a multiplication between power and time: an average upgrade of annual operative time of a week is as

effective as an upgrade of machinery efficiency of about 2%, which isn't always easy to get.

Any optimization has the final aim to improve the plant cash-flow: this paper is focused on this aspect, that we could call "financial efficiency".
By the way, there is another aspect to take into account: the environmental efficiency. Although it doesn't increase the plant output, it's usually required to keep the licence, improving the perception of hydro power into the public opinion.

The question

Concerning the financial efficiency, the question is to what extend it's worth improving the efficiency.
In one hand, every one point of efficiency increases the energy production and so the turnover, but, in other hand, it needs additional costs.
Is it more convenient to spend more money today and receive a higher income tomorrow or to save money today for less revenues tomorrow?
The answer requires a typical cost-benefit analysis.

Of course, the convenience strongly depends on the energy price, but the benefits are also influenced by the legal framework, especially for renewable energy sources, which are supported by European and national Authorities.

The legal framework for HPP optimization

The Italian framework implements the European one, particularly the EU Directive 2001/77. In order to achieve the Kyoto protocol target, and recently the new 2020 target, renewable energy sources (RES) are strongly supported by the law.

Small hydro power plants (up to 10 MW) and run-of-river plants of any power have the opportunity to choose between selling electricity to the G.S.E., a public company, and selling it to the market; in the second case, their electricity has transmission priority.
But the most important support is due to the green certificates. The relevant producers and importers of energy from conventional sources are supposed to put a percentage of renewable energy on the national grid. That rate is today 4.55%. In spite of that, they could purchase green certificates from RES producers. So green certificates are an additional revenue for new hydro energy.

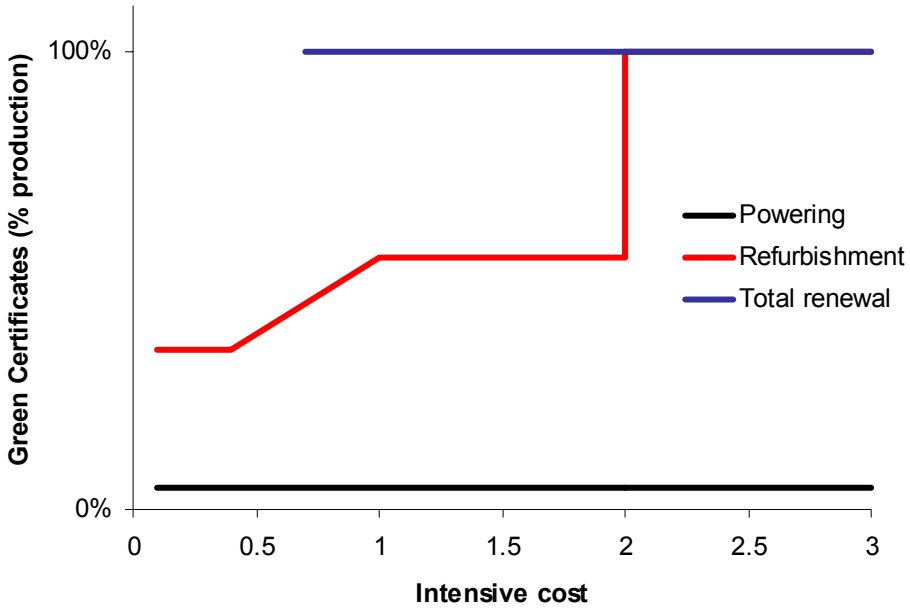
The public support is not aimed to give higher profits to plants owner, but to increase the electricity produced from the RES mix. Italy is very far from the national target of 25% stated for 2010 by the European Authorities[1]. Without any public support, it would be much more convenient producing electricity from the conventional sources: higher is the total income for RES energy (included the green certificates) and higher will be the percentage of RES electricity gained.

The total amount of energy produced by hydro power is the sum between the output of new plants and the production of the old ones, which are the majority: without relevant investments on existing plants, their production will fast go down.
On the contrary, the optimization of those plants could obtain a huge potential additional production.
For that reason, the decree of October 24th 2005 grants green certificates not only to new plants, but also to powered and refurbished ones.
The intensive cost of powering must be at least € 100 per kW, but the amount of green certificates realized is always 5% of the annual production.
Only refurbishments that have included the change of all the hydroelectric machinery receive green certificates on all the additional production and also on a percentage of the historical average energy.

	Intensive cost	**Green Certificates**
Powering	≥ 0.1 M€/MW	5% production
Refurbishment (new units)	≤ 2 M€/MW	additional prod + % historical prod (depending on cost: generally 20-50%)
	≥ 2 M€/MW	100% production
Total renewal		100% production

The amount of green certificates increases according to the cost of refurbishment, from an intensive cost of € 400 per kW to one of € 1,000 per kW, but the relation is complicated and depends on many variables.
If the cost is at least € 2,000 per kW, the producer will receive green certificates on all energy production; the same happens for plant completely renewed.

[1] Annex to the Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.



In that way green certificates support the plant upgrading: the operating margin grows and it becomes convenient getting an higher efficiency.

The evaluation process

The choice of the plant optimization project needs a cost-benefit analysis. After the identification of any task which could contribute to the efficiency upgrade, we have to evaluate the specific additional production obtainable. Then we could compare the consequently further revenues to the costs of the tasks.

Generally speaking, there are also some interventions that are strictly necessary to ensure plant operating, although they aren't able to get a significant additional production or any additional production at all. They include works imposed by Authorities, for instance to improve environmental efficiency or plant safety standards, and tasks due to the plant ageing. As existing hydro power plants became older, they need more frequent and more expensive maintenance works, with losses in time availability and average annual production. The causes are very various: wear of water seals and clearances, inefficiency of complementary equipments (typically trashracks) or control devices, difficult supplying of spare parts, especially hardware, etc.. Sometimes, those problem lead to the substitution of a part or of an entire unit even though it still has a good technical efficiency.

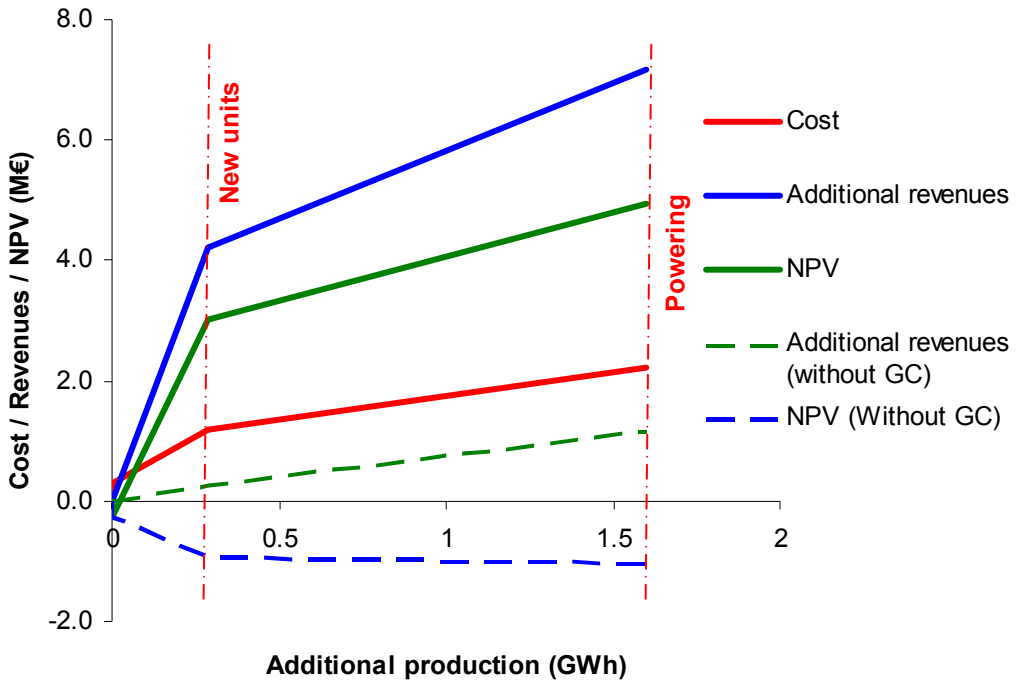
Regarding the financial efficiency, the best option is the sum of tasks that has the maximum cash-flow, in addition to the ones strictly necessary to the plant operating. As far as the total cash-flow is positive, it could be convenient to include other interventions, despite their negative contribution to the cash-flow.

A case study

As case study, we present the optimization of the Parre facility, a small SHP on the river Serio, in Northern Italy, existing since 1935.
The old plant included the weir, the intake structure, the inlet channel and a powerhouse with two units: a Kaplan turbine and a Francis one.
The refurbishment works took place between June 2006 and May 2008 and involved a partial rebuilding of the plant.
The conceptual design took into account two different options: the change of the previous units with two similar ones or the powering of the plant, with an upgrade in capacity and head. That second option, that we chose, needed a new powerhouse and the installation of a penstock connecting the channel to the new unit.
The Authorities ordered additional tasks: the consolidation of the riverbank opposite to the powerhouse, a new fish passage and the discharge, at the weir, of the environmental flow rate.

	Before	After
Maximum flow rate	7.50 m^3/s	10.00 m^3/s
Average flow rate	6.50 m^3/s	7.68 m^3/s
Head	7.20 - 8.00 m	8.44 m
Units	1 Kaplan + 1 Francis	1 Kaplan
Power	480 kW	750 kW
Production	2,900 MWh	4,500 MWh

The optimization had a total cost of € 2,212,440.51 and permitted an average additional production of about 1,600 MWh a year.
As shown by the following chart, the chosen option has the highest efficiency upgrade and also the best cash-flow; without the public support any option would have been convenient and so any optimization could have been done.



Reliability of foreseen efficiency

The choice of the best financial option is based on the foreseen efficiency, but what assure the plant owner that it would be really achieved after the interventions and the expenditure?
Which could be the preventive actions to minimize the risk of financial losses?

Coming back to the initial classification of the different meanings of efficiency, a good evaluation of the available hydraulic resource is needed to gain the expected technical efficiency. The head could be measured with a high precision, but the water level in the outlet channel typically changes according to the downstream flow rate. The most critical aspect is the estimation of the flow rate, which requires a data bank as larger as possible, not easy to get even for an existing plant.
The item of machinery efficiency deserves some words apart and it is treated in the next chapter.

The improvement in operational efficiency can be foreseen by the analysis of the historical unavailability time and of its related causes: this is an advantage that we have only for existing plants.

Concerning the financial efficiency, we couldn't pretend the stability of the prices of electricity and green certificates. Instead, the stability of the legal framework is a reasonable expectation, strictly necessary to maintain investor confidence for long pay-back time investments, such as HPP optimization projects. The EU itself set a transitional periods of at least seven years, for any proposal of a new support scheme[2].

Measurement of machinery efficiency and penalties

The expected machinery efficiency has a great importance in the optimization of a hydro power plant: the choice of the units supplier among the manufacturers is strongly influenced by the proposed value and, of course, it dramatically affects the plant cash-flow.
But the efficiency declared by the possible suppliers would remain just an act of faith if it wasn't previously evaluated, contractually defined, on site tested in the commissioning phase and subjected to penalties, in order to discourage too much optimistic declaration in the tender phase.
The preliminary evaluation, of both efficiency and tolerance, should be based on the efficiency measured on other similar machines, manufactured by the same supplier, and on the tolerance achievable with the declared testing method.
The penalties aren't supposed to be less than the total amount of financial losses caused by a value of efficiency eventually lower than the declared one.

It's easy to realize that the financial losses caused by a lack in the expected efficiency can be significant; so the hydraulic efficiency measurement has a crucial role to guarantee the achievement of the rentability of each rehabilitation project, from both the technical and the financial point of view.

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[2] Directive 2001/77/EC, article 4, subsection 3(c).