

# ONE PLANT FOR EIGHT: PROBLEMS AND SOLUTIONS TO RECOVER THE ABANDONED SHPs IN THE HEART OF GARDONE VAL TROMPIA TOWN

## **Claudio Baldussi**

Municipality of Gardone V.T.  
Via A. Mazzini, 2 - 25063 Gardone V.T. (BS) - ITALY  
Tel.: +39-030-8911583  
Fax: +39-030-832706

## **Nino Frosio**

Studio Frosio  
Via P. F. Calvi, 9 - 25125 Brescia - ITALY  
Tel.: +39-030-3702371  
Fax: +39-030-396143  
e-mail: [studio\\_frosio@iol.it](mailto:studio_frosio@iol.it)

## **SUMMARY**

A typical constraint of the old water energy exploitations was that they had to be very close to the energy utilisation facilities, because hard technical problems affected the transport of the energy in its mechanical form. So we can understand why, at the beginning of the century, eight very small plants were built to exploit the energy potential of the river Mella water diverted in a long, old canal - called *Acqualunga* - crossing the heart of Gardone V.T..

The actual facilities of the electric large net allows to recover the whole energy potential by means of one plant, which represents the only chance to reduce the building and the operating costs to an acceptable amount assuring a correct revenue to the project.

## **1 Historical remarks: a stage of Leonardo da Vinci at Gardone V.T.**

Leonardo da Vinci, whose interest in the water potential exploitation is well known, is said to have been in Gardone V.T. to study an unusual exploitation of the running water potential, the so called "tromba idro-eolica" [hydro-eolic fan], a remarkable invention of an anonymous smith of this little, but very active, town in the Brescia province.

By means of this peculiar device, the smith could generate an air flow for its forge without any mechanism – like bellows or similar - but only applying the velocity effect of the running water, in a time when it was likely ignored.

Whether this stage at Gardone V.T. of the famous engineer, living at that time in Milan, really happened or not we don't know- but a plan of Val Trompia sites certainly plotted by the hand of Leonardo really exists in the Vatican Library – anyway this is an evidence of the remarkable level achieved in the exploitation of the water energy potential in Val Trompia.

The map dated 1761, where the many water mills existing at this time are carefully quoted, is an indisputable historical document about that. Its curious purpose was to illustrate the damages, which a dramatic flood of the river Mella caused to the mills, in order to get some support from the Central Government (the Republic of Venice).

In this map we distinguish the original plot of the *Acqualunga* canal, where the plants described in this paper are located. In the Napoleon map, dated 1810 an extraordinary amount of water mills are represented, ready for the industrial era just coming.

## **2 Description of the plant**

The aim of project, ongoing under the management of the Gardone V.T. municipality, is the rehabilitation and the upgrading of a small hydro plant, once owned by a military factory, concentrating here the head of other seven very small plants existing upstream, which were decommissioned during the last fifty years.

The water comes from the river Mella, by means of a weir located in the North side of Gardone V.T.. The drainage area is 241 km<sup>2</sup> with an average rain fall of 1.200 mm per year.

Till now the water runs in a long canal, named *Acqualunga* just for it, crossing the whole town from North to South; in the middle part of it, a secondary canal, called

*Gramineto*, origins. The existing plants are located on the main canal and on the secondary ones: so some of them exploits the whole diverted water amount and some other only a part of it. In the future this partition will be removed and the flow rate will run unchanged in the new penstock.

The present maximum flow is 4,0 m<sup>3</sup>/s, corresponding to an average flow rate of about 3,0 m<sup>3</sup>/s. In the final stage of the project, the maximum flow rate will increase to 5,0 m<sup>3</sup>/s to guarantee anyway an average flow of 3,0 but under a reserved flow obligation which is supposed to increase dramatically.

## 2.1 THE ABANDONED SHPs IN THE HEART OF GARDONE V.T.

The actual plot of the Acqualonga canal is the results of a many years work, to keep the exploitation of the water resource at its best, relating to the need of every historical period. Side to side with the agricultural use of the water, the steel craft, a very typical activity of Val Trompia since the Roman time, stimulated the exploitation of the energy potential of the water, at first, as usual, by mills and then, since the beginning of the twenty century, by small hydro plants.

But in the last fifty years, the technical progress and, most of all, the thermal production by oil, made easy and cheap to buy energy instead of the traditional self producing, and that caused the dismissing of many small energy plants from indigenous renewable sources. The same happened to the small plants existing on the Acqualonga and Gramineto canals, whose characteristics are resumed in the table.

<b>Name</b>	<b>Canals</b>	<b>Qav m<sup>3</sup>/s</b>	<b>Gross head m</b>	<b>Nom. capacity kW</b>	<b>Decommissioning date</b>
<i>Bernardelli</i>	<i>Gramineto</i>	1,2	2,90	34,12	1987
<i>Beretta I°</i>	<i>Gramineto</i>	1,2	2,60	30,59	1943
Beretta II°	Acqualonga	1,8	3,45	60,88	1940
<i>Beretta III°</i>	<i>Gramineto</i>	1,2	2,44	28,70	1943
Redaelli I°	Acqualonga	1,8	8,35	147,35	1995
<i>Redaelli II°</i>	<i>Gramineto</i>	1,2	4,20	48,23	1995
Redaelli III°	Acqualonga + Gramineto	3,0	3,75	110,29	1991
SFAE	Acqualonga + Gramineto	3,0	10,05	295,59	1982
<b>Theoretical</b>		<b>3,0</b>	<b>25,60<sup>(3)</sup></b>	<b>755,75</b>	

## 2.2 THE NEW SHP OF GARDONE V.T.

The energy potential recover has started from the downstream plant, called SFAE plant. The works mainly involved the internal structures of the power house, to adapt it to the new equipment, taking into account the scheduled upgrading, which will led the plant to its final stage.

The main characteristics of the new plant in the final configuration are:

- Max flow rate 5,00 m<sup>3</sup>/s
- Gross head 27,30 m
- Nominal capacity 803 kW
- Installed capacity 1.300 kVA
- Expected production 5.000.000 kWh

The optimum penstock diameter has been calculated in 1.800 mm, which allows to

<sup>(3)</sup> The plants in italic are in parallel, so their heads are computed only once in the theoretical head.

increase of 6,64% the head exploitation, in comparison with the old situation, thank to the recover of the unexploited heads existing between every two contiguous plants. That is an excellent result, taking into account that a long penstock will take the place of the headrace open canals and that one plant only will replace eight ones.

The first 550 m of the existing canal will remain unchanged; only a new trash rack and an automatic cleaner will be installed.

Then the water begins to run underground in a penstock 1.360 m long laying, where possible, in the plot of the existing canals.

Particularly, the first 220 m of penstock are obliged to run under the state road of Val Trompia; the following 405 m follows the burdens of a new residential area and finally the penstock enters into the existing canals for the last 735 m.

The power station and the tailrace, 360 m long, will remain about the same of the last downstream plant.

### 3 The problems & the solutions

The design had to match many technical topics to get the plant configuration which would be both reliable and cheap, without forgetting the small size of the plant. We looked for a difficult equilibrium between the recover of the existing buildings and equipment - which means a plant cheaper but less reliable - and the erection of new ones - which means a plant more expensive but more reliable too.

#### 3.1 THREE EXECUTION PHASES

The running time of the project can't be the technical one, because of the hard constraints affecting its implementation. The authorisation time and the small erection period (only 20 working day in August) for the first part of the penstock under the state road; the interference with relevant new buildings involving a large part of the canals; the financial procedures of the Municipality; made a cocktail of constraints which changed the usual planning of such a project.

After a deep analysis we collected all the constraints in three building and operating steps, everyone autonomous from the others, defined as follow.

Phases	Gross head <i>m</i>	Max flow <i>m<sup>3</sup>/s</i>	Max capacity <i>kVA</i>	Cost <sup>1</sup> <i>Euro</i>	Beginning	End
1	10,05	4,0	390	850.000	2000	2001
2	13,95	4,0	520	300.000	2001	2003
3	27,30	5,0	1.300	1.700.000	2003	2030
<i>Final stage</i>	<i>27,30</i>	<i>5,0</i>	<i>1.300</i>	<i>2.850.000</i>		

#### 3.2 REHABILITATION OF THE EXISTING PENSTOCK

The existing penstock of SFAE plant was an interesting chance to lower the costs but it was necessary to check it from the hydro and structural point of view.

So we made a survey to collect data on the thickness of the penstock and its geometry and the results have suggested the measures to be taken.

Stability and resistance analysis have been made according to the geometry and to the design loads.

Briefly we can say that the old penstock can bear the stress coming from the water pressure (about 4 bar), but not the one caused by the external loads and the vacuum.

We realise that the negative results of the tests depend on the penstock thickness which the corrosion has reduced to less than half compared to the original value.

As a consequence of those analysis, we thought to rehabilitate the penstock by means of the following works.

- Inclusion of the penstock in a concrete box of about 2,40 x 2,40 reinforced with a steel net.

---

<sup>1</sup> Excluding VAT only.

- Internal sand-blasting.
- A coat of inorganic galvanising film 70 µm thick.
- Two coats of epoxy-vinilic film up to 250 µm of total thickness.

In this way we solve the problems of internal and external protection to corrosion and the ones connected to the fact that the existing penstock is not suitable for the external loads.

### 3.3 THE NEW PENSTOCK

The main technical problems are connected with the installation of large diameter penstock (1.800 m): with low internal pressure but very high external loads (road loads). We take into consideration the following options, sorted by increasing costs.

Material	Int. pressure	External loads	Durability	Erection	Cost
GRP	sufficient	problems	good	very good	1
cast iron	very good	better than steel	better than steel	very good	2
steel	excellent	instability problems	corrosion problems	good	3
concrete	permeability problems	excellent	excellent	sufficient	4

At the end we have adopted an original solution: a very thin (6 mm) steel pipe coated around by 25 cm steel reinforced concrete, so that the steel pipe waterproofs the structure and assures the necessary strength for the internal pressure, while the concrete bears up the external weights well and guarantees a good protection against the rust. A problem could be the erection time, longer than the other options one.

So we intend to adopt the cast iron option where the erection time is a critical parameter. That occurs in the first (upstream) part of the penstock, where it lays under the state road of Val Trompia, the only one connecting Gardone V.T. to the world !

### 3.4 ELECTROMECHANICAL EQUIPMENT PECULIARITY

Another remarkable technical topic is connected with the three phases of the project which should be carried out without dramatic adjusting to the electromechanical equipment. The turbine is designed to run with good efficiency during the first and the second phases, which are characterised by a little head variation (from 10,05 to 13,95), but also to produce at its best when the head increase to 27,30 m. We'll get this goal changing the gear ratio to carry the running speed of the turbine to the correct value under the new head without changing the generator speed.

### 3.5 BY PASS FACILITIES

Some unusual solutions have been found to discharge the flow rate when the group goes out of operation. In the first and third phase, the penstock inlet is too far from the river and the exceeding flow will be discharged at the power station, while in the second phase a short canal carries to the river the water coming from the spillway located at the beginning of the penstock. Summarising, the situation will be:

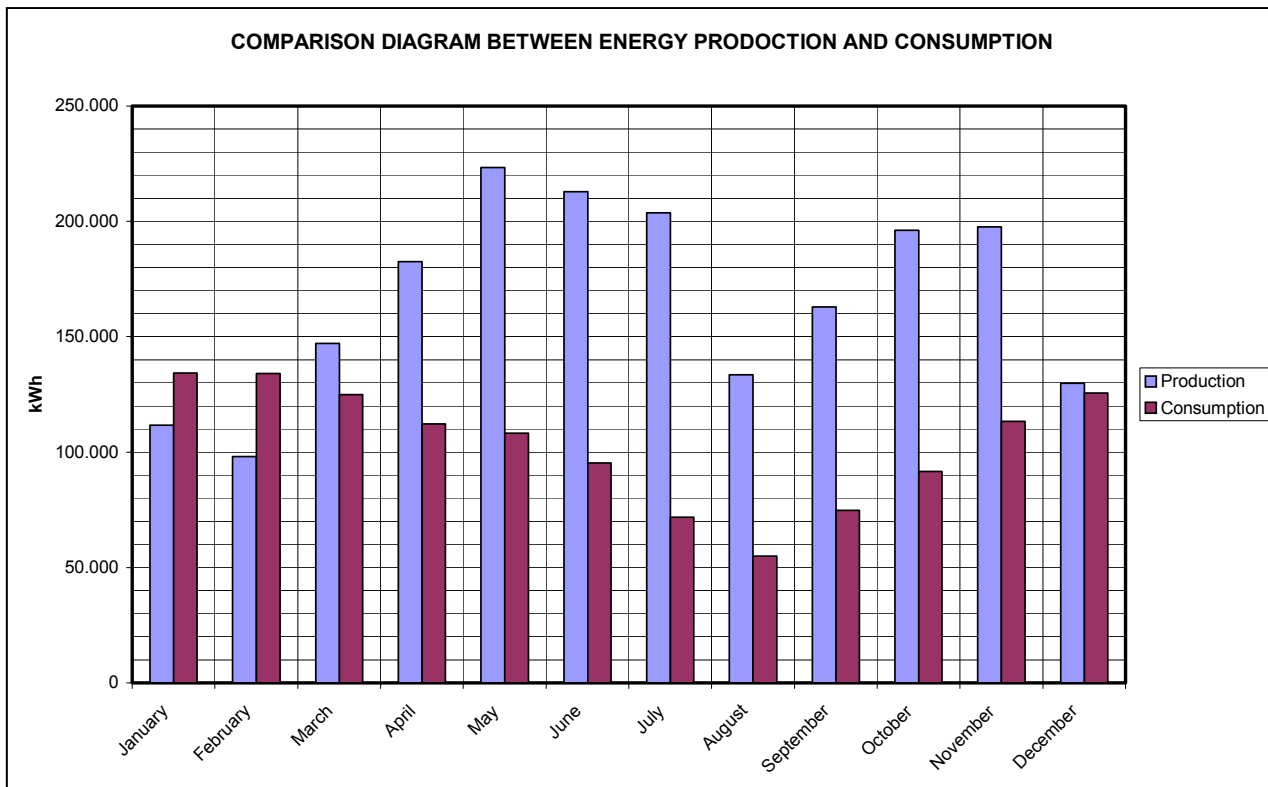
Phase	Discharge type	Discharge location
1	Spillway	Beside the piezometric chamber near the power station
2	Spillway	At the beginning of the penstock
3	Dissipation valve	In the piezometric chamber near the power station

### 3.6 INCREASING THE VALUE OF THE PRODUCED ENERGY

Nowadays there is a great uncertainty about the value of energy produced by renewable sources. Incentives based on fixed prices and purchase obligation by the national utilities are running short, but the new support framework, already stated

compatible with the free market, like the green price, the green portfolio and so on is not effective yet.

In this situation, it is necessary to take into consideration different hypothesis about the produced energy destination. Luckily, the promoter, the Gardone V.T. municipality, has many expensive uses of the electric energy which could, in any



case, be covered by the production of the new plant. In the following diagram you can see the comparison - monthly - between the Municipality uses and the plant production.

Taking into account the income of the overproduced energy sold to utilities (at very low prices), the cost of the lacked energy bought from utilities (at very high prices), the energy transport fees and losses, the produced energy value is prudently assumed 0,052 EURO/kWh.

### 3.7 INVESTMENT AND FINANCING

The costs can be summarised in the following way (in EURO)

<b>Task</b>	<b>Phase 1</b>	<b>Phase 2</b>	<b>Phase 3</b>	<b>Final stage</b>
Turbine & Generator	370.000	0	0	370.000
Electric plant	150.000	0	15.000	165.000
Penstock	140.000	260.000	1.260.000	1.660.000
Civil work	190.000	15.000	60.000	265.000
Gates & Trash rack	18.000	5.000	80.000	103.000
Others	10.000	5.000	50.000	65.000
Design & supervision	82.000	25.000	115.000	222.000
<b>TOTAL</b>	<b>960.000</b>	<b>310.000</b>	<b>1.580.000</b>	<b>2.850.000</b>

The financing figure is:

EU grant		Municipality		Private investors		Total	
675.000	23%	1.270.000	45%	905.000	32%	2.850.000	100%

The specific costs assume the following values:

- Capital cost of the installed kW: 2.740 EURO
- Capital cost of the kWh: 0,57 EURO

These investment parameters are high, but justified by the type and the city location of the plant.

Thank to the EU support (KONVER program) the financial parameters are quite good. For example the IRR (Internal Rate of Return) is 12,28%, taking into account the EU grant.

#### 4 Conclusion

The design of a small size plant in such a different condition as the one in Gardone V.T. is never profitable if the energy price remains as low as it is nowadays.

In this specific case we could begin the erection because we can rely on some economic helps and some deriving advantages in addition to the simple production of energy, even if valuable because green.

In particular:

- Grant of 675.000 EURO from the EU by the KONVER program (recover of military structures for industrial purposes).
- Absolute need of a private investor to change place to the existing canals in order to make important buildings.
- Value increasing of existing buildings which take great advantage of the place changing of the underground canals (maintenance costs, wet and floods problems, constraints to the building use).
- Recover of the old canals plot as a seat for the municipality technological plants, like drink water pipes, sewerage system, gas pipes, electrical lines.

All those items have given a basic contribution to lead the Municipality and the private investors involved in the project to find the necessary funds for the construction of the new Gardone V.T. small hydroelectric plant.