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Planning and restoring of small hydropower stations for small basins : actual conditions and potential developments.

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Abstract

In this paper the study of water sources availability for a small Ligurian catchment is discussed. In the basin under study (located next to the France boundary) a serie of small hydropower stations are planned to be restored. This renewed interest for hydropower stations can be attributed both to an increasing local electric demand, and to the funds recently provided by the Italian government to encourage alternative/suppletive forms of energy. Starting from few measures available: rainfall, runoff data, the work aims to investigate basin underwater storage and make accurate real time forecasts with a focus on critical conditions for hydropower reservoirs. For these purposes, an empirical model approach has been used. Nevertheless, the authors believe that when poorly monitored catchments are discussed, very complex and data demanding models should be discouraged. Herein, meaurments of rainfall (P), and streamflow discharges (Q) can be obtained easily as compared to others like soil characteristics, initial soil moisture, rate of infiltration ...

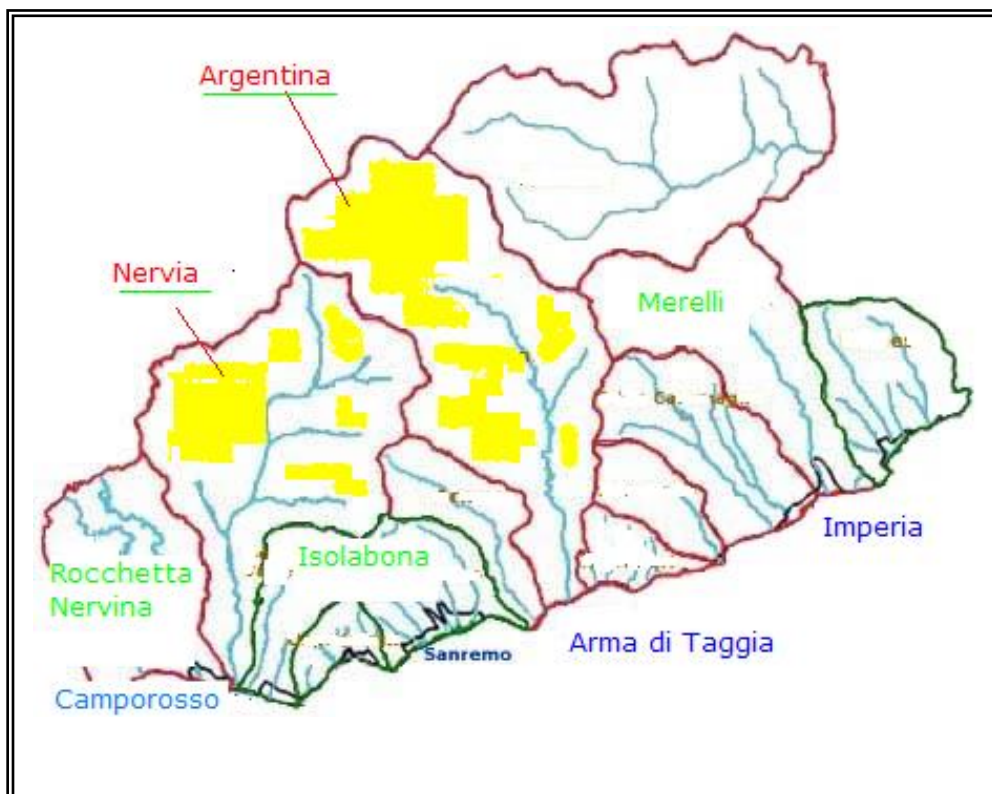
1. Introduction

Nowadays, following data reported by CENSES analysis , there are 35 Mino Hydroelectric (<3 MW) stations at work in the entire Liguria Region, with an overall power of 68 MW and producing 275 GWh which equals to 4.6% of the total energy consumed in the region. Besides government and European incentives (the so-called green certificates) and the expectations proposed by Regional Laws (LR 308/1982) it is arguably true that, there is an upward limit to the development (which is planned around 7%) of hydropower stations mostly due to the torrential and irregular behaviours of its streamflow courses. However, even though power station producibility is far to satisfy local domestic demand, it is indeed true that they can act as ‘‘compensation reservoir’’. In this work the study of a dis-used hydropower station located over Argentina River catchment (near

the French boundary) is presented. The study of feasibility for the restoring of the station has been set aside to a streamflow measures campaign in order to better check streamflow regime mostly during drought periods and also in order to insert a given intervention over a streamflow in an overall scenario of the river course under study. The paper is organized as follows : in chapter 2 the catchment is presented, in § 3 describes the measures available, §5 the adopted model is introduced and finally results and conclusions are drawn in chapters §6 and § 7, respectively.

2. Catchment description

The model is applied to data from a small Ligurian catchment: Argentina in north-western Italy, located near the Tirreno sea coast, near the French border .Two sequences of 20 years (1952-1971) of daily streamflow, measured at Merelli for the Argentina River, obtained by applying the Thiessen method to data from at least six measurement stations inside the catchment and seven nearby, were used. The Argentina watershed (192 km² in size) extends from Monte Saccarello to Arma di Taggia, and its 39 km stream length is dominated by a very high and rough course with sharp drops. Several tributaries join the watercourse, the major ones being the Carpasina, Oxentina and Corte Rivers. Elevations vary from 2199 m at Monte Saccarello (which is the highest Ligurian mountain), 1776 m at Collardente and 1626 m at Monte Ceppo, to sea level at Taggia, which lies on the coast. The Argentina catchment has an overall mean slope of 5.56%. We have estimated a minimum down flow value for Argentina River of **160 l/sec** following the prescription of LR 36 of January/5/1994.



3. Streamflow measures description

In order to investigate the river course water availability several direct streamflow measures

have been conducted both in the section under study called Loreto of Triora and Merelli to be able to link local measures to the unique hystorical streamflow serie available for the River Argentina. The catchment size at Loreto is 40 km², at Merelli 192 km² while the total size at the River Delta is 207 km². Measures have been conducted approximately once every month, particular attention has been devoted during summer period where the problem of water availability is most critical. A calibrated whirlpool is generally used in such cases. In this work a 12 cm of diameter whirlpool made by S.I. A.P. (Strumenti Italiani Alta Precisione) of Bologna has been adopted. The device works as follows: while the stream runs over the propeller a meter counts the number of turns which will be further convert into water speed. The procedure is carried out by dividing the section under study in a hydrographical reticle with a mesh of different sizes (thick at the sides an broader at the center) and by multiplying each node speed by its area of influence, as denoted by the following formula:

$$Q = \sum_{i=1}^n \Delta A_i \cdot v_i \quad (I)$$

Where Q stands for the total streamflow measured. The table reported below (Table 1) summarizes the registrations conducted. Streamflow values are expressed in *l/sec* while the unitary contribution in *l/sec*Km²*.

Date	<i>Section .1 Loreto</i>	<i>Section 2 Merelli</i>	U.C.1	U.C. 2
30/06/06	115		2.85	
12/07/06	47		1.17	
20/09/06	285		7.07	
4/10/06	195		4.22	5.13
28/10/06	295	1710	7.32	
14/11/06	155	805	3.85	
20/01/07	145		3.60	3.42
30/03/07	83		12.06	1.86
26/04/07	250			
31/05/07	397		8.86	10.16
20/06/07	349	975	7.82	19.18
31/07/07	39	217		
13/08/07	49	267		1.13
29/09/07	67	252	1.66	1.18

4. Choice of hystorical data

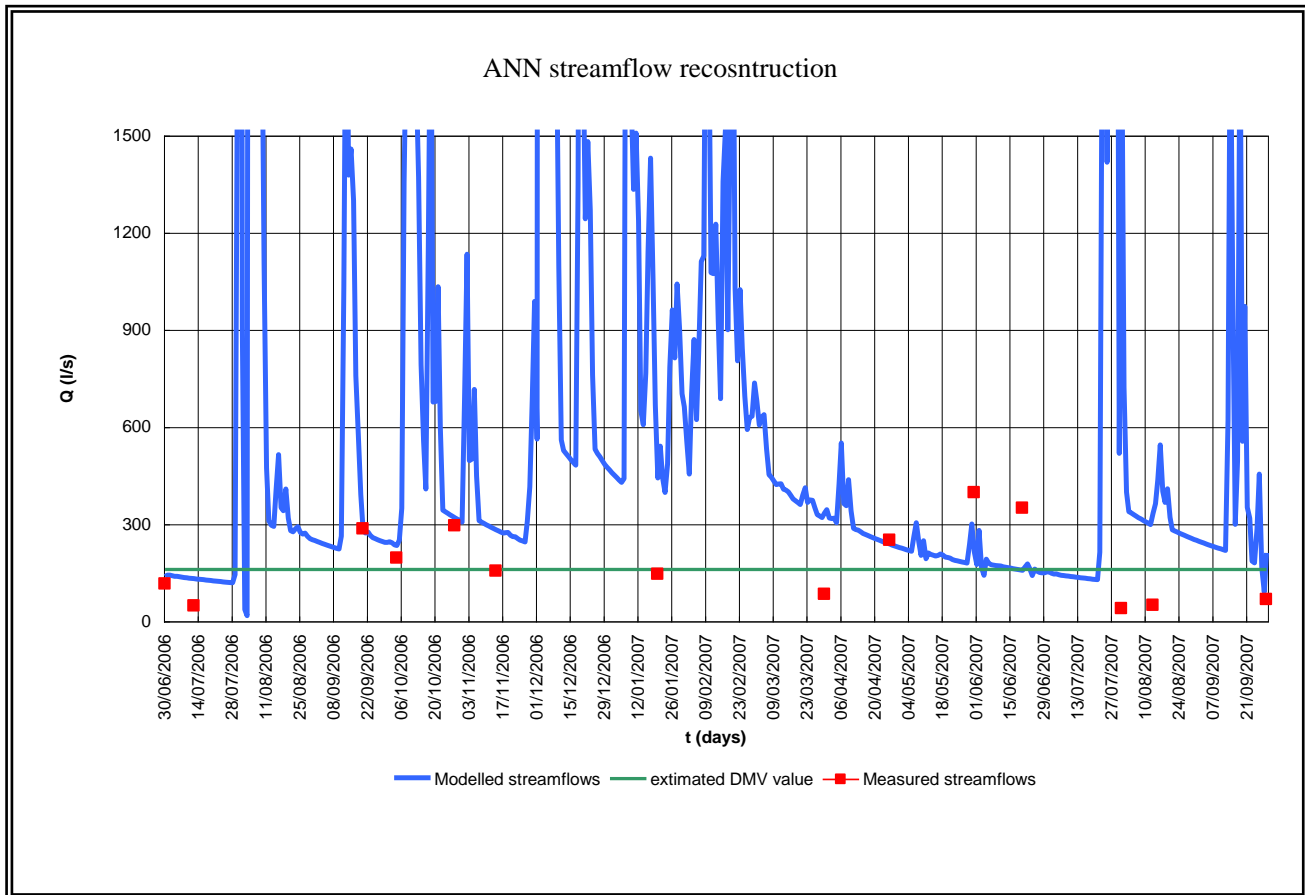
The daily rainfall and streamflow series are continuous for the section of Triora starting from 1952 to 1971, with the exception of 1964 where rainfall data are not provided. The other hystorical rainfall gauges located over Argentina basins and nearby are: Centrale Argentina, Colle Melosa , Colle Belenda, Tavole and Ceriana. Triora and Centrale Argentina are the only two that have guaranteed continuous registrations without big gaps in data and can be considered the most reliable pluviometers for the upper (40 Km²) and lower (192 Km²) part of the basin. Unfortunately most of these gauges , recently checked by A.R.P.A.L. Institute of Genova have been removed, thus having only two at work: Triora and Montalto Ligure while the unique historical streamflow gauge available is located at Merelli. In such a scenario of very poor data available over one of the biggest western Ligurian catchment, we have decided to run the model using data referred to directly to Triora section by using Triora rainfall record and by ‘referring’ Merelli streamflow to Triora. Fictitious stremflows have been built taking into account both the ratio between the two different sub-basin surface and the minimum value of the ratio between unitary contribution which is equal to **0.828**.

5. Model adopted

ANNs (Artificial Neural Networks) are essentially parametric models, whose generality is ensured by precise theoretical results. An empirical iterative calibration procedure allows the user to find appropriate values for the parameters of an ANN by from an arbitrary starting point. There are two major ANNs learning paradigms: supervised and unsupervised learning. In supervised learning, network outputs are compared to given targets and error feedbacks are employed to train the ANN. Examples are MLP (MultiLayer Perceptron) and RBF (Radial Basis Function) networks. In unsupervised learning there is no set target to achieve, and the network must discover interesting categories or features in the input data. Kohonen self-organizing maps belong to this category. In this work supervised learning will be adopted. A MLP network is formed by a set of sensory units that constitute the input layer (set of input variables), one or more hidden layers of computational nodes (neurons), and an output layer of computational nodes. MLP training is the most widely used example of supervised learning, by which the network outputs are compared with known answers and feedback about the errors incurred is generated. A teacher (e.g. data relating to physical reality) tells the network what the right answers are; and through an inductive learning approach the network is able to generate rules from given examples and then generalize its predictive ability with a different data set during the validation phase. Within this framework, ANNs fall into two categories. In a feedforward neural network, knowledge is acquired during training, which consists of a forward pass (1st phase) and a backward pass (2nd phase). In the first phase information travels from each layer to the subsequent one, through weighted sums and activation functions of the hidden units; and at the end of each forward pass modelled outputs are compared to given targets, and the Mean Square Error (MSE) is evaluated .

6. Results

The model has been calibrated and validated over the entire data set available, considering the hystorical period from 1952-1971 linked to the very recent years 2006-2007 during which direct measures campaign has been conducted. Recent data have been provided by the A.R.P.A.L . Imstitute of Genova. The modelling relies only on rainfall value as inputs mostly due to high costs of recent data. Once the model parameters have been evaluated the model has been used for generation furnishing for the dates where the measures have been conducted the following results :



giving a RMSE equal to **386.78** l/sec.

7. Conclusions

The ANN have demonstrated to give an acceptable value of discrepancy between the modelled and measured streamflow despite the very few measures available and a total modelling based only on rainfall data.

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