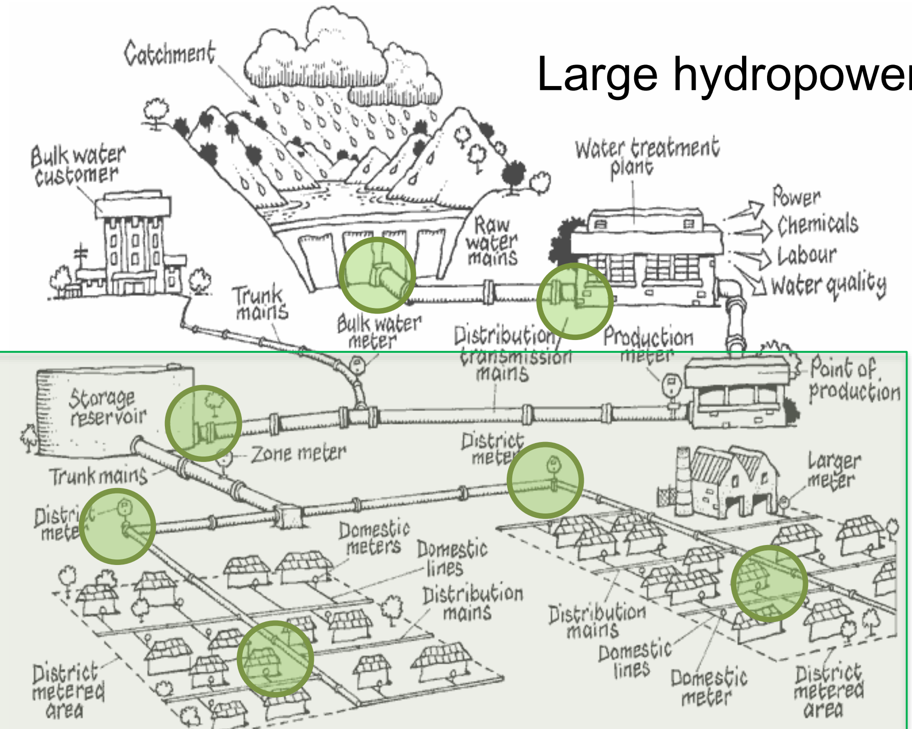
Optimization of low-head hydropower recovery in water supply networks

Irene Samora

Introduction

Water supply systems

Where can we produce hydropower?



Large hydropower

Small hydropower

Micro hydropower

Source: Queensland Environmental Protection Agency and Wide Bay Water Corporation (2004): Managing and Reducing Losses from Water Distribution Systems. A series of 10 manuals

Introduction

Water supply systems

Urban water supply networks are complex systems where pressure and flow discharge vary constantly.

Their main purpose is to supply water to the population within comfortable limits of pressure.

Which type of turbine could be profitable in such conditions?

Where should they be placed?

In this work: the 5BTP turbine is presented
a search algorithm for water supply network is proposed
the test is performed in the whole supply system of Fribourg

Methodology

Search algorithm

Use of a search algorithm to optimize the location of N turbines in a given network while respecting pressure limits. A simulated annealing process was chosen.

$$f(X) = 1/\mathrm{NPV}_{20\ \mathrm{years}}$$

$$E_t(X) = \rho g \Delta t \sum_{n=1}^{N} \eta_{tgn} \eta_{fn} Q_n H_n$$

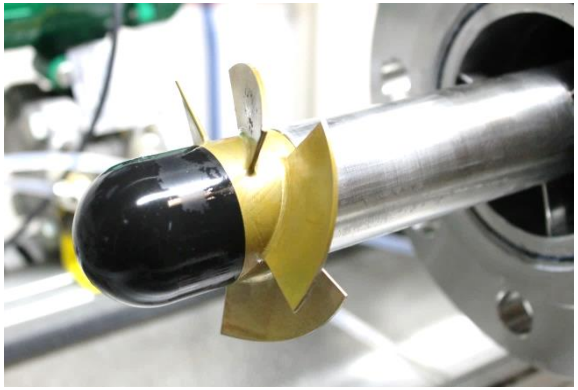
$$NPV = revenues - investment\ costs$$

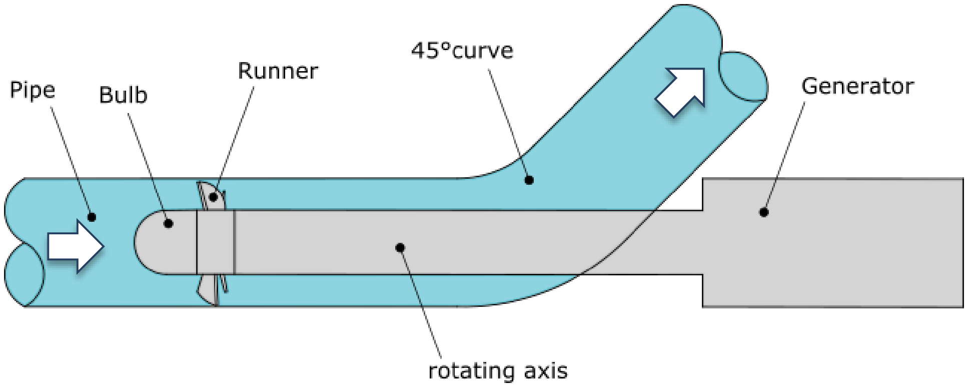
$$revenues = tariff \sum_{t=1h}^{20\,years} E_t$$

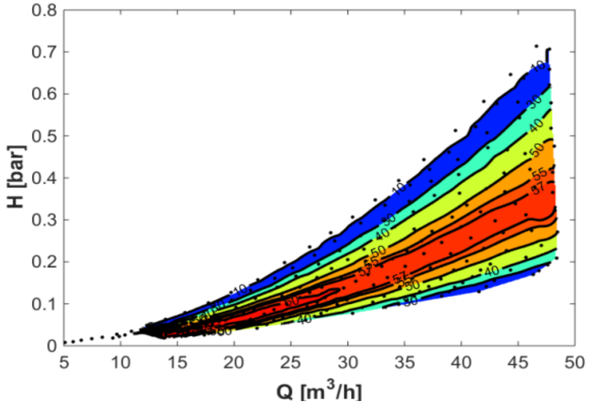
investment costs = equipment costs + civil works costs + engineering works costs + miscellaneous costs

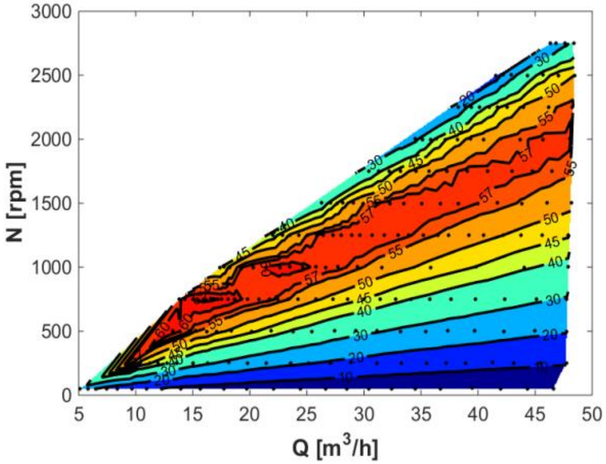
Micro-hydropower plant

The five blade tubular propeller (5BTP)



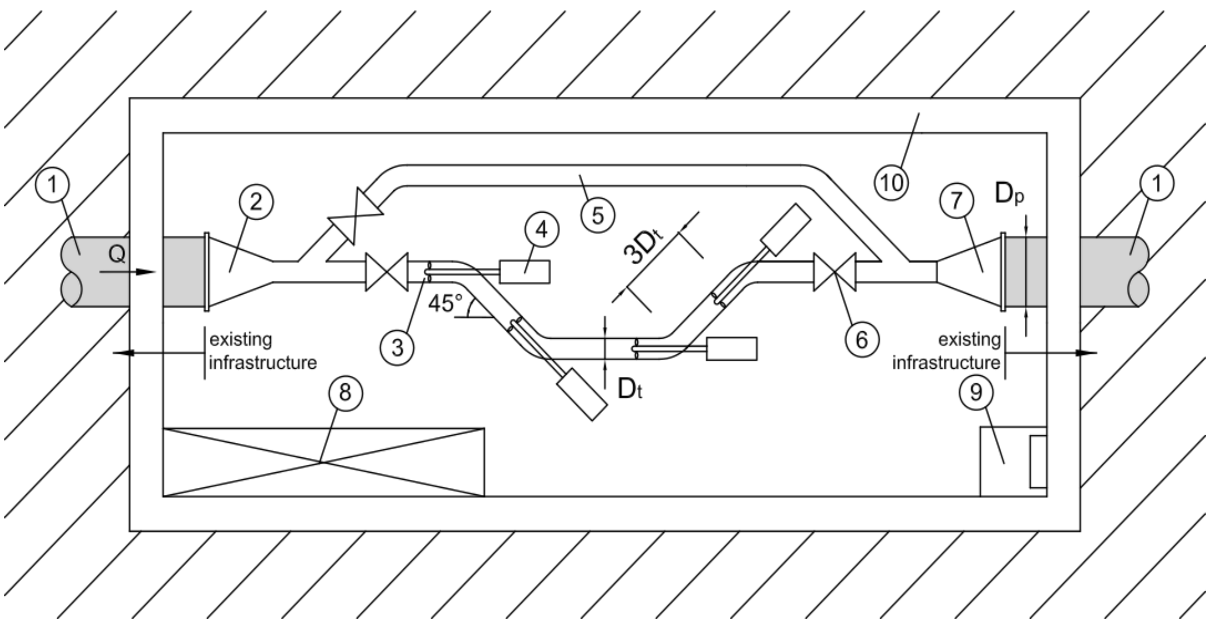






Micro-hydropower plant

Buried chambers



Legend:

1 – Existing pipe (D_p);

2 – HP contraction taper;

3 – Turbine runner module (D_t)

4 – Generator;

5 – By-pass (D_t);

6 – Isolation valve (D_t);

7 – LP enlargement taper;

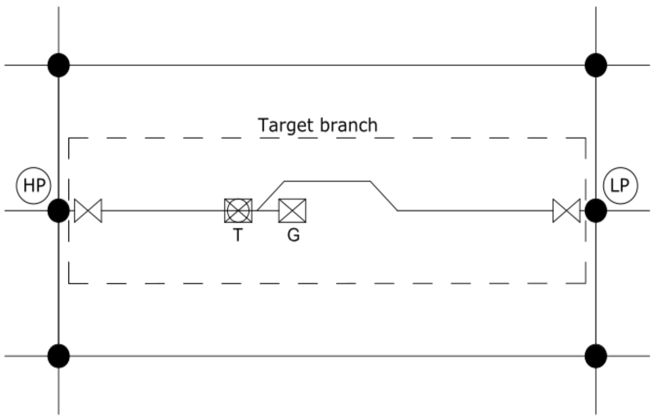
8 – Electric cubicle;

9 – Access;

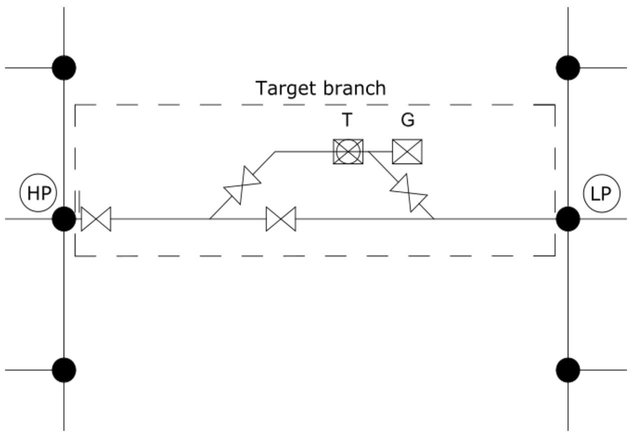
10 – Concrete chamber wall

Micro-hydropower plant

Redundancy



Type A – 1 turbine

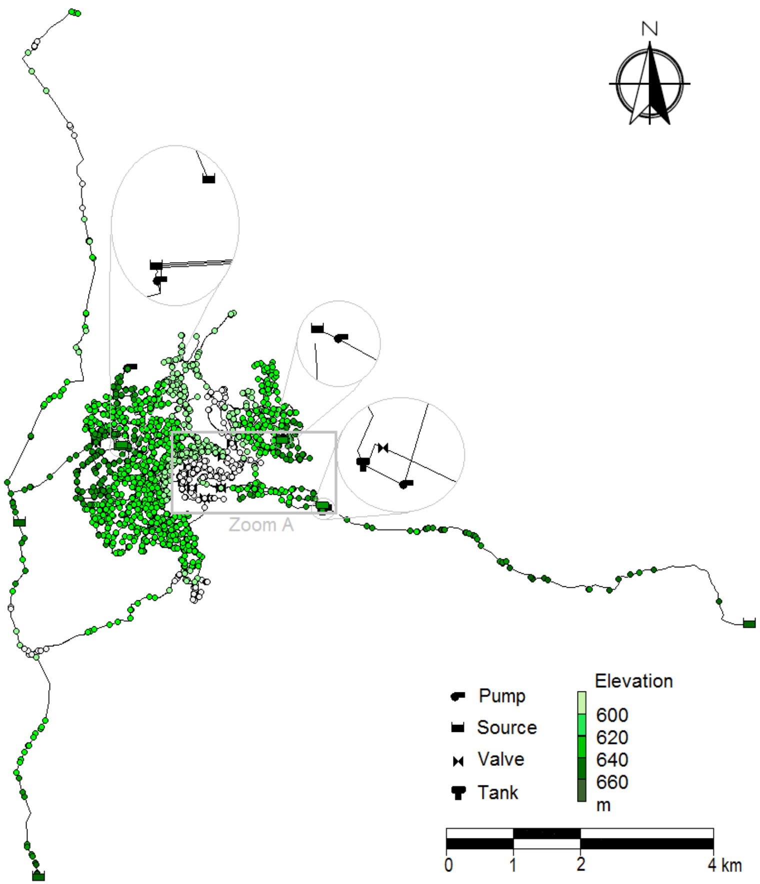


Type B – 1 turbine

The lack of redundancy influences the costs since there is the need for a by-pass

Case study

The city of Fribourg



Characteristics

2972 links
2805 nodes
9 PRV
1 water tanks + 6 sources
4 pumps

Restrictions

30 m of minimum pressure in consumptive nodes

Fixed levels in water sources

Daily total variation in the water tank

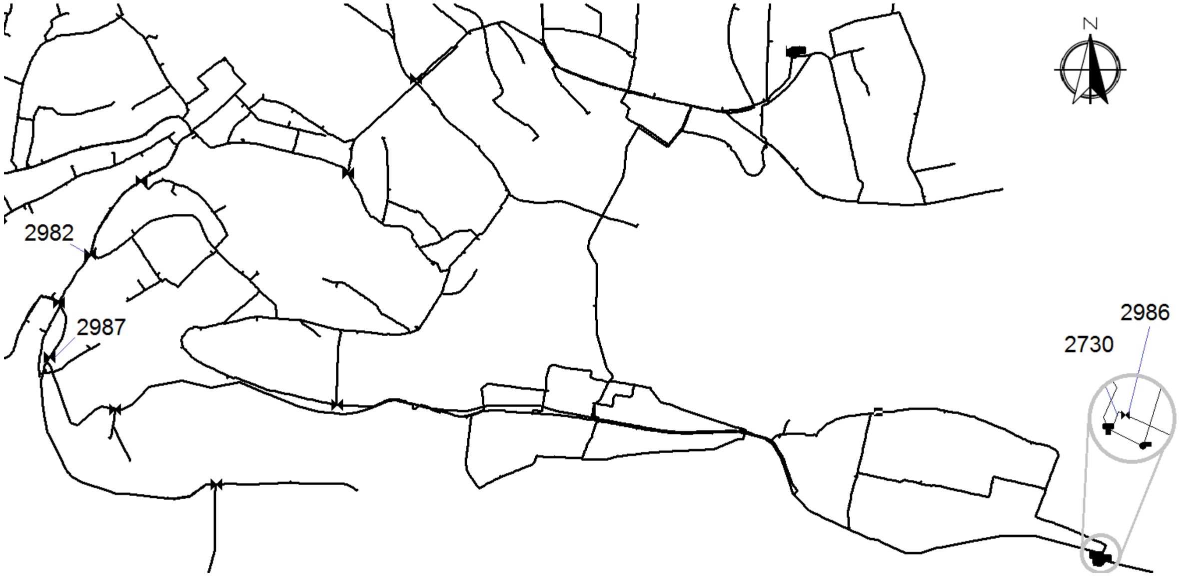
Case study

Consumption

Daily pattern

Equal consumption in all consumptive nodes

Results



Best solution	X	E (MWh/year)	$NPV_{20years}$ (k$)
Best solution	2986	60.5	258
	[2986, 2986]	120.9	521
	[2986, 2986, 2986]	131.7	569
	[2986, 2986, 2986, 2987]	136.2	586
2nd best solution	2730	60.5	250
	[2730, 2730]	120.9	513
	[2730, 2730, 2730]	131.8	561
	[2730, 2730, 2730, 2987]	136.2	575
3rd best solution	2987	1.5	5
	[2987, 2987]	1.3	5
	[2987,2987, 2987]	1.1	4
	[2982,2982, 2987, 2987]	1.6	5

The pipe with higher potential is located in one of the main paths of water supply to the city.

If a by-pass would be required in all chambers, the maintenance valves would represent 20-30% of the total IC, according to the unit prices assumed.

Conclusions

Inline micro-hydropower plants have been conceived for installation in meshed urban water systems.

Optimal locations in Fribourg are on one the main pipes, in the path with the highest discharge flows and existing PRVs.

The best solution with two 5BTP turbines is expected to produce 121 MWh/year.

The maintenance by-pass represents 20-30% of the total of investment costs, compulsory if no local supply redundancy exists.

I. Samora, M. J. Franca, A. J. Schleiss and H. M. Ramos, “Simulated annealing in optimization of energy production in a water supply network”, Water Resources Management, 2016, 30(4): 1533-1547.

I. Samora, V. Hasmatuchi, C. Münch-Allígné, M. J. Franca, A. J. Schleiss and H. M. Ramos, “Experimental characterization of a five blade tubular propeller turbine for pipe inline installation”, Renewable Energy, 2016, 95: 356-366.

I. Samora, P. Manso, M. J. Franca, A. J. Schleiss and H. M. Ramos, “Opportunity and economic feasibility of inline micro-hydropower units in water supply networks”, Journal of Water Resources Planning and Management, 2016.

Thank you for your attention!

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Acknowledgments to

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

EAU DE FRIBOURG
FREIBURGER WASSER

ribi

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

LCH LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

TÉCNICO LISBOA